Russian Academy of Sciences
Nuclear Safety Institute (IBRAE)
B.Tulskaya 52, 113191, Moscow Russia
http://www.ibrae.ac.ru

Overview of IBRAE Activities

Prof. Leonid Bolshov,
Director

IBRAE Origin

- IBRAE was set up upon the Chernobyl accident to carry out fundamental investigations and independent analysis of nuclear and radiation safety
- Decree of the USSR Council of Ministers No2198r, November 3, 1988

Scientific Directions

- Safety of Nuclear Power Facilities
- Ecological Impact of Nuclear Power Facilities on the Environment and the Population
- Emergency Response

Scientific Directions

- Safety Concept for Nuclear Submarines Decommissioning and Utilization Under Present Situation in Russia
- Concept of Nuclear Power Development
- Expert Geoinformational Systems for the Fuel/Power Complex Applications

New directions
Ecological risks

- A comparative analysis of ecological risks.
- Safety for the nuclear spent fuel treatment.
- Methodology of assessing the risk of nuclear fuel cycle.

New directions
Ecological risks

- Radiological terrorism (system analysis).
- Analysis of normative-legislative base for the environment protection.
- Public relations.

IBRAE Staff

- Total staff — 400 persons
- Scientific staff — 306 persons
- Doctors of science — 27 persons
- Candidates of science — 120 persons

Specialists in:

- Theoretical and applied physics;
- Nuclear power engineering;
- Biophysics;
- Radioecology;
- Computational mathematics;
- Informatics.

Institute Scientific Divisions

- Division of Physical-Technical Safety Problems of the Fuel-Power Complex Facilities.
- Division of Ecological Safety and Radiation Risk.
- Division of Mathematical Modeling and Information Technologies.

IBRAE partners and sponsoring organisations

EMERCOM of the RF	Federal program, contracts
Minatom of the RF/ Rosenergoatom	General Agreement, contracts
Ministry of Defense /Navy	Agreement, contracts
Gosatomnadzor (GAN)	5-year program, contracts
RSC «Kurchatov institute»	Contracts
Experimental-design office (Nizhnii Novgorod)	Contracts
Experimental-design office «Gidropress»	Contracts
SPA «_ayak»	Contracts
VNIIEF «Arzamas – 16»	Joint projects
Mintopenergo, RAO EES	Contracts
Gasprom	Agreement, contracts

IBRAE partners and sponsoring organisations

US NRC	General Agreement, contracts
US DOE	Agreement, contracts
US DOD	Contracts
IRSN, France	General Agreement, contracts
CEA, France	General Agreement, contracts
FZK, Germany	Contracts
OECD	Agreement, contracts
EU	Projects
INTAS	Projects
PNNL, ANL, BNL, ORNL, SNL	Projects, contracts

IBRAE Funding Structure for 1998/1999/2000

- **Russian Academy of Sciences** **15%/15%/15%**
- **Domestic Customers** **35%/50%/55%**
- **Foreign Customers** **50%/35%/30%**

Nuclear safety

- **Probabilistic safety analysis (PSA). Development of methods and their applications.**
- **Deterministic safety analysis. Development and application of computer codes on NPP safety analysis.**

IBRAE Structure:

- Director.
- Deputy Directors.
- Scientific Advisory Board.
- Scientific Departments.
- Dissertation Council.
- Base Desk of the Moscow Physical-Technical Institute.
- Technical crisis center.

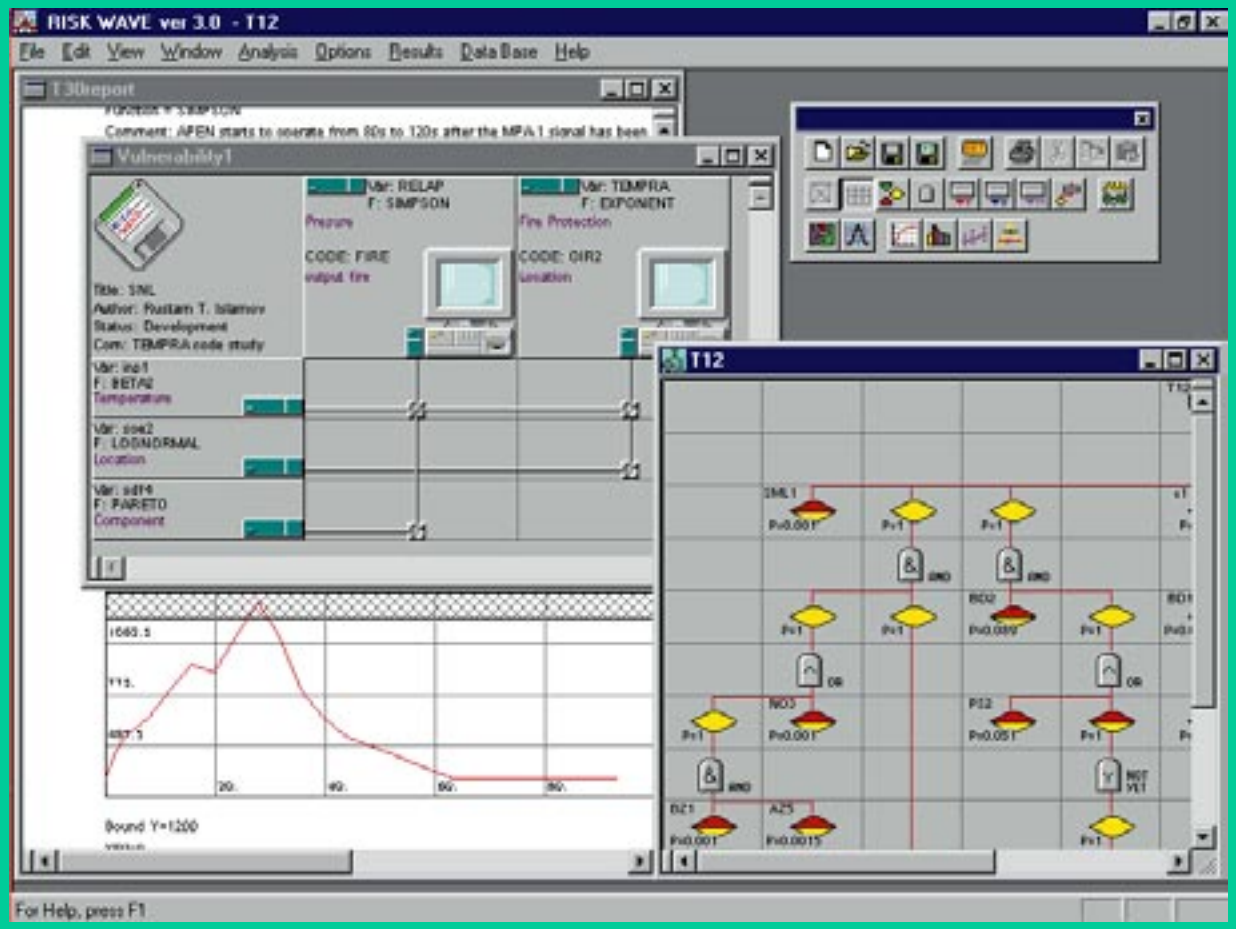
Institute Scientific Divisions

- Division of Physical-Technical Safety Problems of the Fuel-Power Complex Facilities.
- Division of Ecological Safety and Radiation Risk.
- Division of Mathematical Modeling and Information Technologies.

Nuclear safety

- **Probabilistic safety analysis (PSA). Development of methods and their applications.**
- **Deterministic safety analysis. Development and application of computer codes on NPP safety analysis.**

Analytical and statistical method PSA-1



Project SCAT

Phenomena	
Codes	Validation

FP behavior out of containment	
Nostradamus	

Physical behavior of containment	
CONT 2D/3D	Sandia 1:6 Kalinin NPP

Reactor core destruction (oxidation, transfer, FP release)	
SVECHA RELIZ	FZK tests CORA, PHEBUS-SFD

Containment phenomena	
KUPOL PROBL	

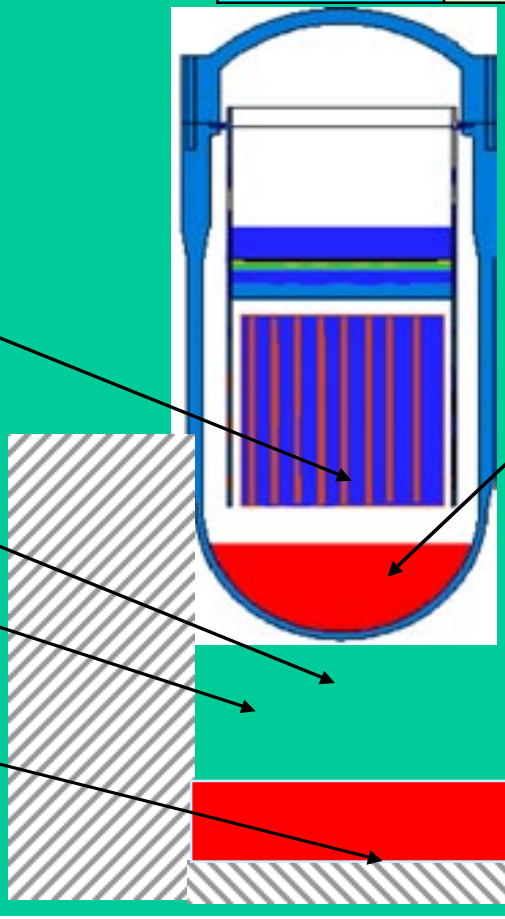
Reactor core melt	
CONV 2D	ACOPO, COPO RASPLAV

Quenching	
QUENCH	FZK Test QUENCH

Physical behavior of vessel	
GEFEST (2D) LOHEY	Sandia LHF tests

Interaction with water	
VAPEX [2]	KROTOS FARO

Interaction of melt with concrete Diffluence	
RASPLAV SPREAD	SURC, BETA, ACE CORINE, KATS



Development of codes and models with IBRAE participation

Organization	Research area
Nuclear Regulatory Commission (NRC) USA (1992–2002)	Development of the severe-accident models at the NPP, code improvement, evaluation, and verification (MELCOR, SCDAP/RELAP5), consolidation of the severe-accident codes
Institut de Radioprotection et de Sûreté Nucléaire (IRSN) (France) (1992–2001)	Development of the severe-accident models at the NPP, code improvement, evaluation, and verification (ICARE2)
U.S. Department of Energy (1993, 1995–1999)	Analysis of the VVER-1000 containment, PSA, code attestation
OECD 1994–2002	RASPLAV/MASKA project for the interaction of the prototype material melt with the reactor vessel (in collaboration with the RSC «Kurchatov Institute»)
Research Center for Nuclear Safety Karlsruhe (FZK) (Germany)	Interaction of the core materials, experimental program QUENCH
OKBM (Russia) 1991–1999	Safety analysis of the reactor VPBER, low-power reactors
Gosatomnadzor (Russia) 1995–1999	Technical support for Gosatomnadzor within the TACIS projects for the NPP safety
ISTC project, in collaboration with IVTAN and OKB «Gidropress», 1993–1995	Concept of the traps for the NPP with the reactor VVER-1000 based on the high-temperature concrete
«Trap» project for VVER-1000 (in collaboration with RSC «KI», NITI St.PbAEP, REA, AEP)	Crucible trap for the Tien Wang NPP with the reactor VVER-1000
St.PbAEP, OTsRK VNIIEF, OKB «Gidropress», AEP, 1998–2001	Development of the Russian code system RATEG–SVECHA for the analysis of the hydrogen safety
OTsRK VNIIEF 1998–2001	Development of the Russian code system for the analysis of severe accidents

Development of codes and assessing hydrogen sources

Goals:

- Development of code for the advanced estimation of hydrogen safety analysis for the project of Lyan Un Gan NPP (China)

Content of work – development and application of combined code

- Thermohydraulics - RATEG (VNIIEF)
- Early stage of an accident - SVECHA (IBRAE)
- Application - RSC «Kurchatov institute»

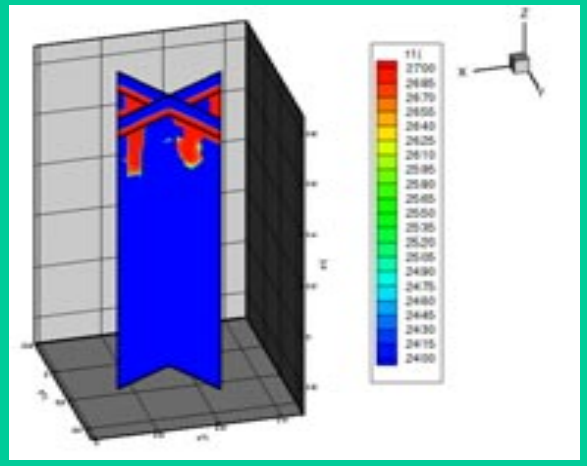
Project Core Catcher

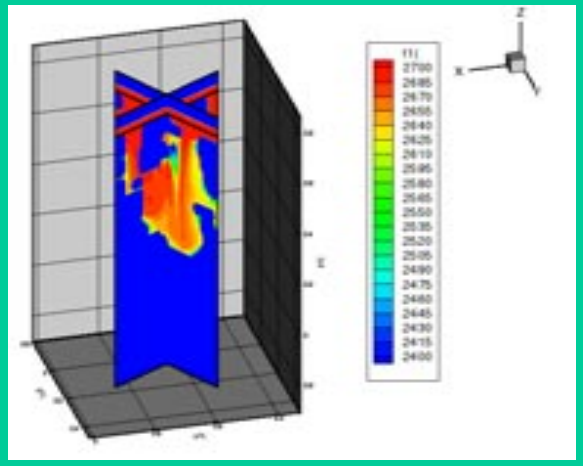
Goals:

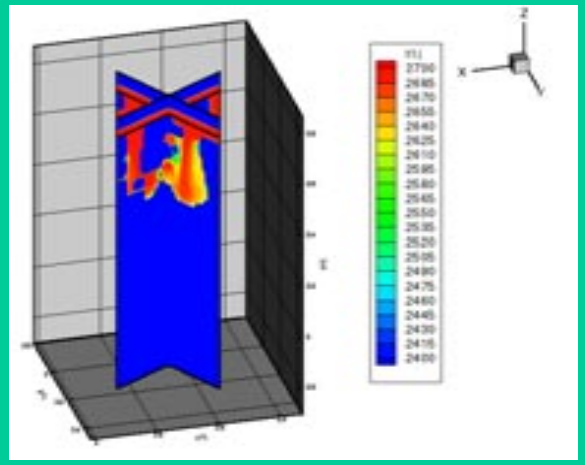
Development and application of Russian tools and codes for core catcher validation in the VVER-1000 project of Tyan Van NPP (China) – Atomenergoproekt (S.-Petersburg), RSC «Kurchatov institute», NITI, IBRAE, PhEI

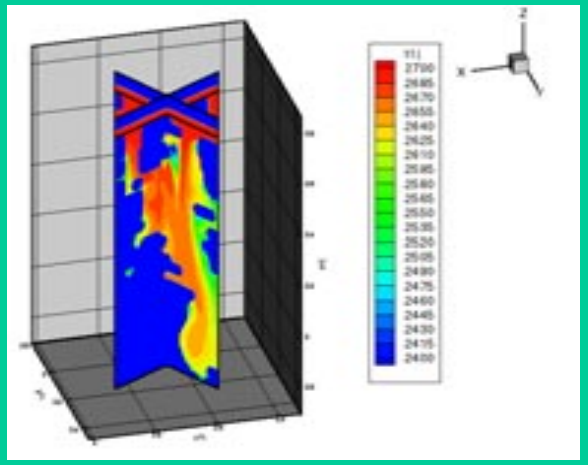
Calculations of processes in catcher using RASPLAV code

Spreading sacrificial materials in core catcher

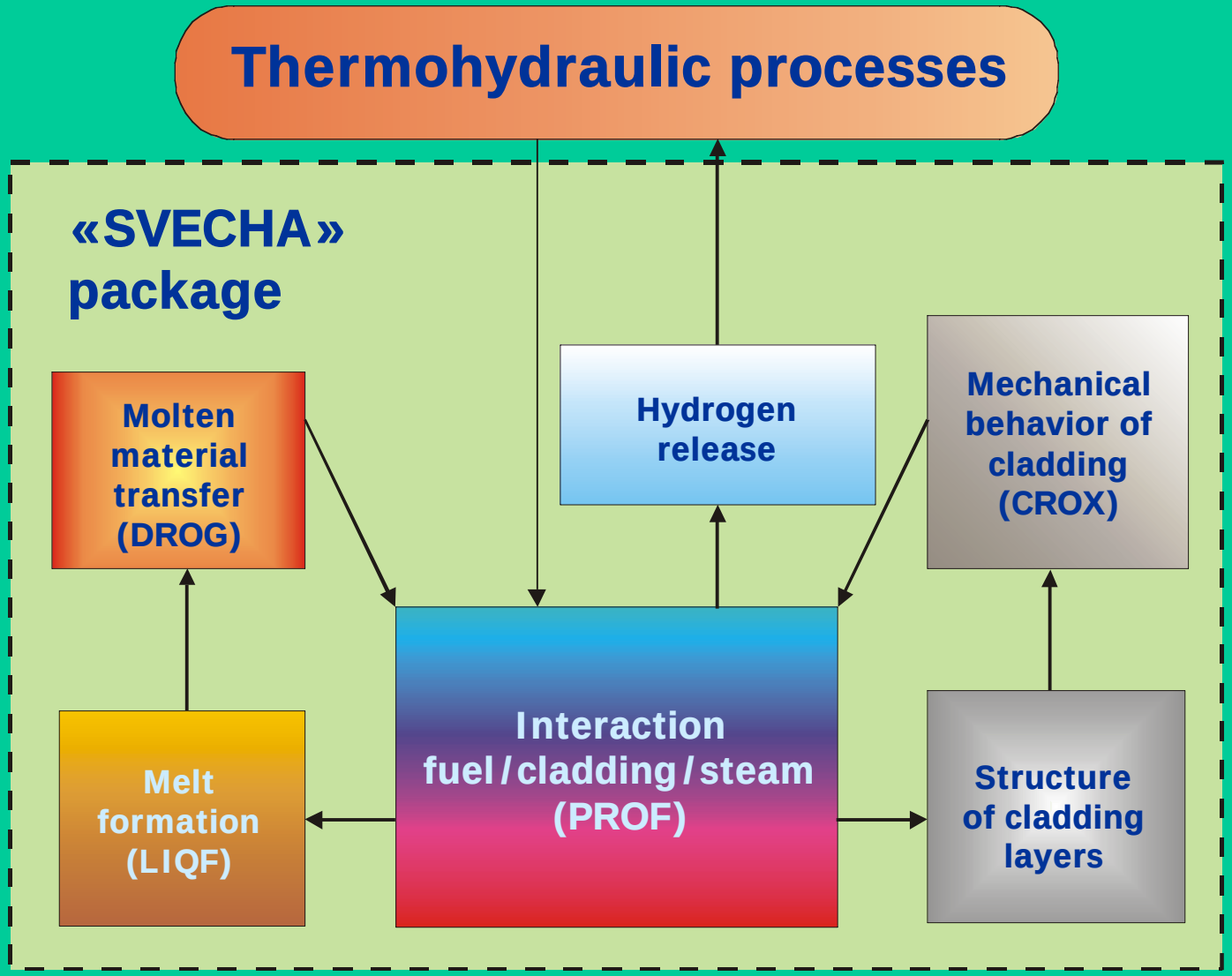




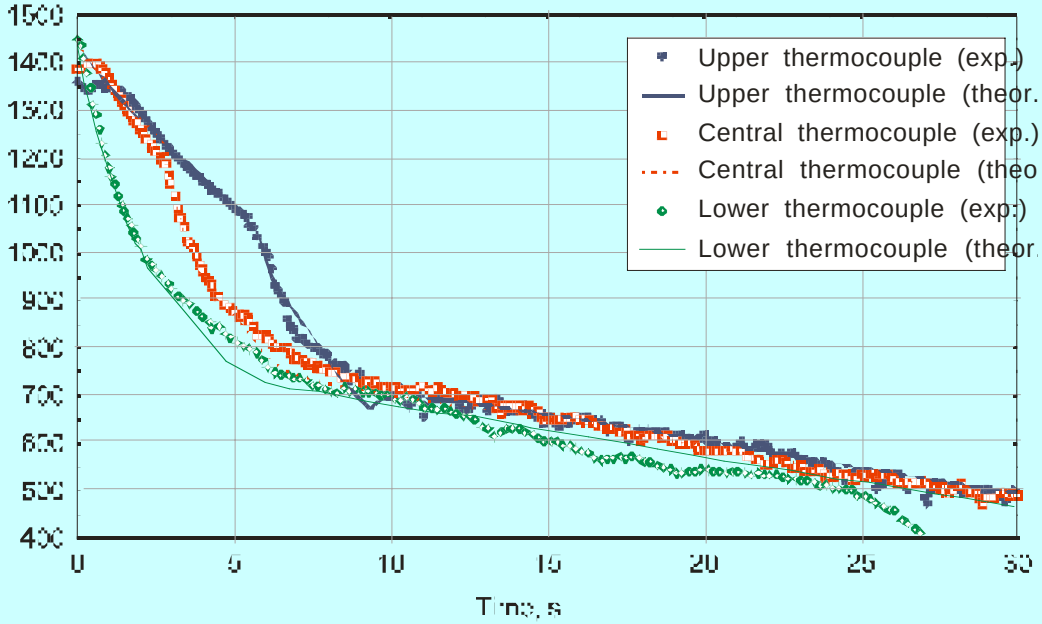




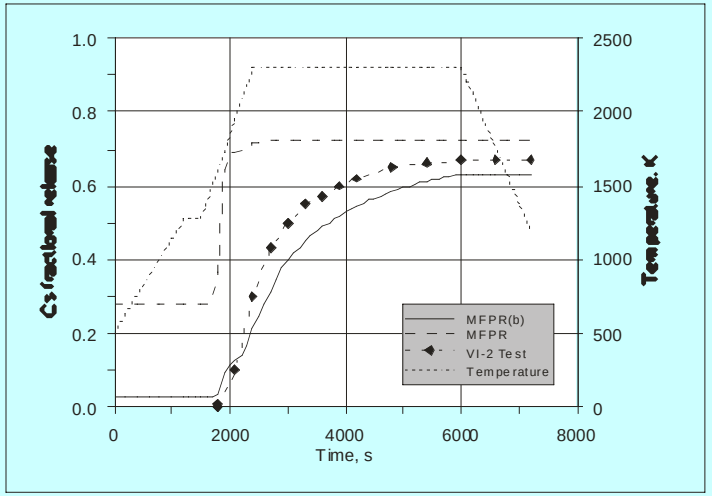
Codes for NPP safety analysis



Codes for NPP safety analysis

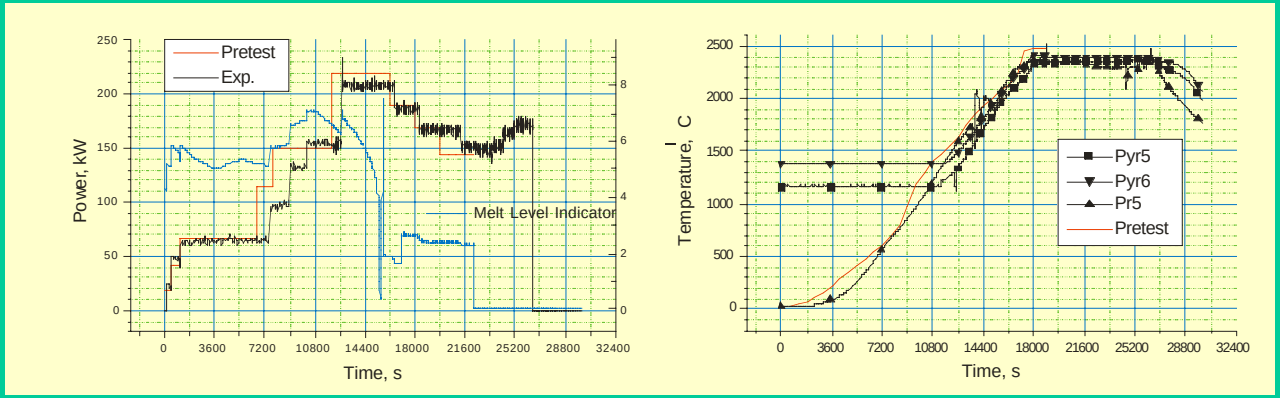


Validation of the SVECHA/QUENCH code package: time dependence of the rod surface temperature

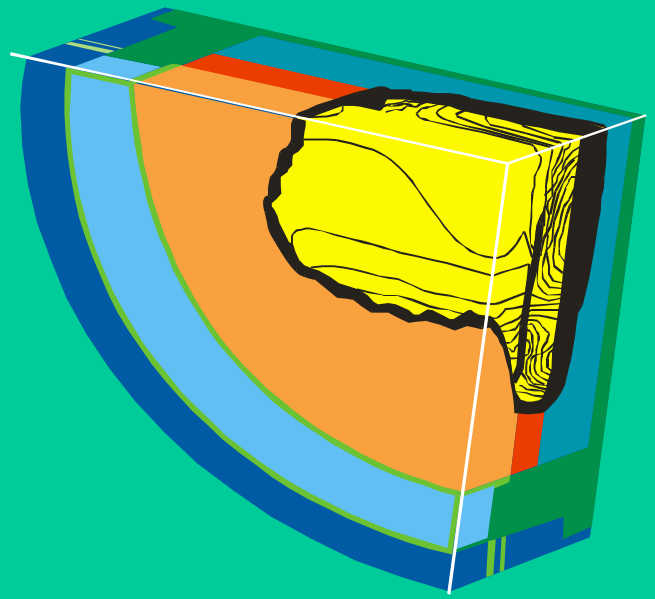


Validation of the MFPR code: kinetics of Cs release in the experiment VI-2 (USA)

OECD Project «RASPLAV–MASKA»



Comparison of the calculated scenario of power injection (left) and corium temperature (right) with the results of AW-4 experiment

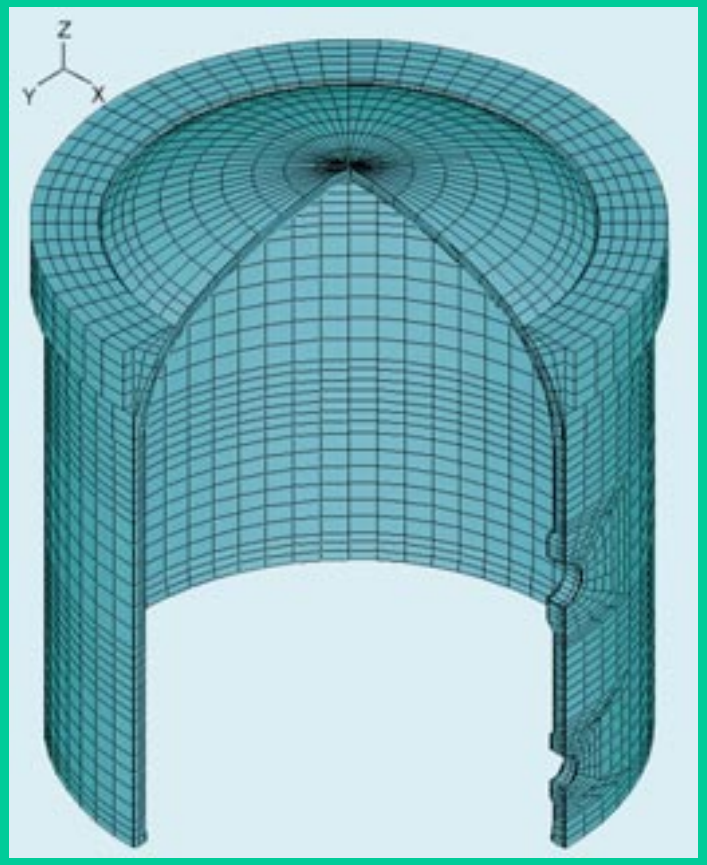


Ingot form and the calculated liquidus isotherm for the experiment AW-200-1

RSC «Kurchatov Institute»

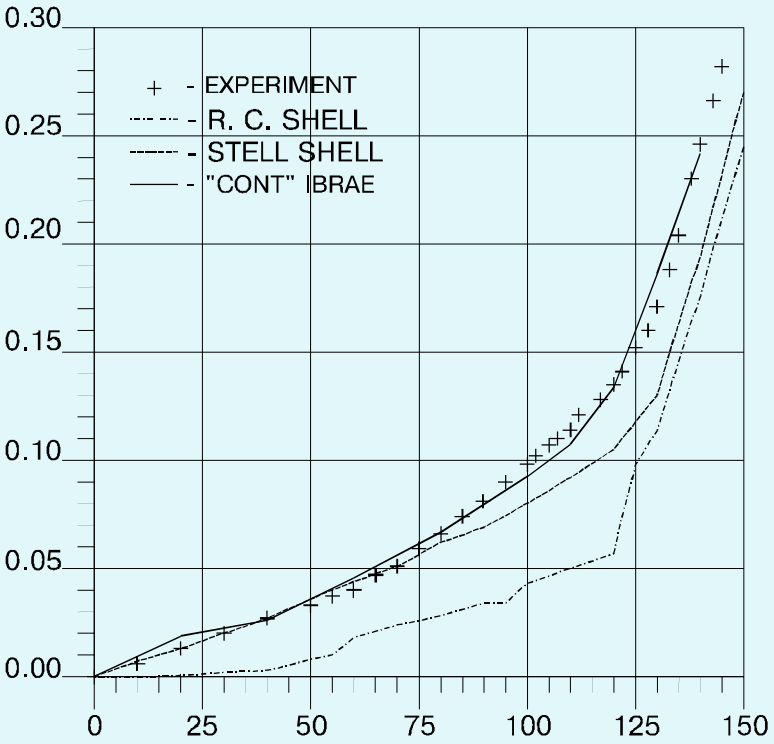
Containment mechanics — CONT code

Model of the prestressed reinforced-concrete containment (Sandia National Laboratory, USA) scaled 1:4

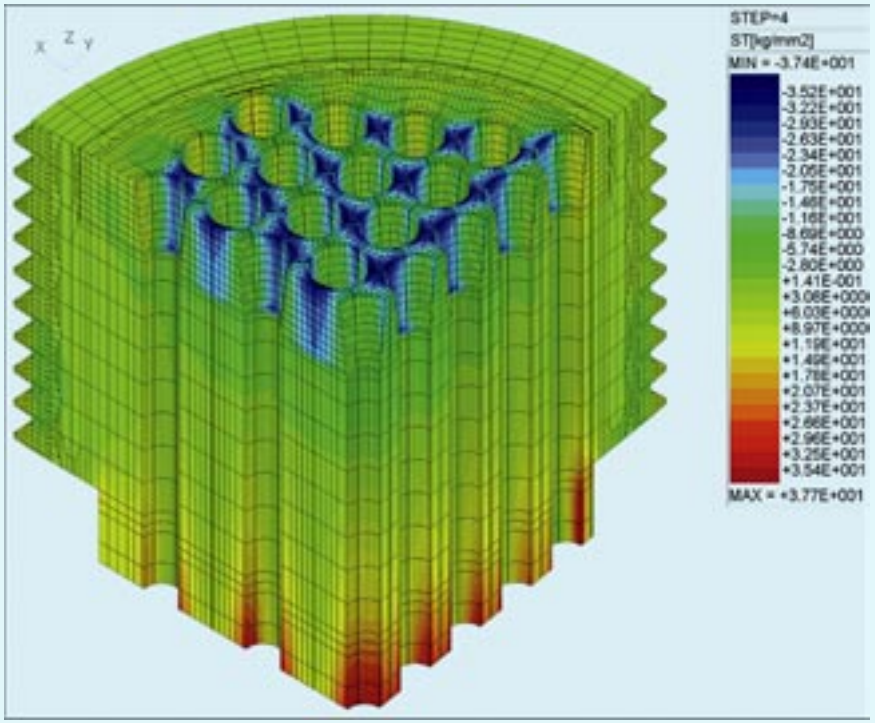


Verification of the CONT code with the SNL containment scaled 1:6. The model allows for concrete crusting by considering reinforcement ropes in the form of thin sheets

Containment mechanics — CONT code



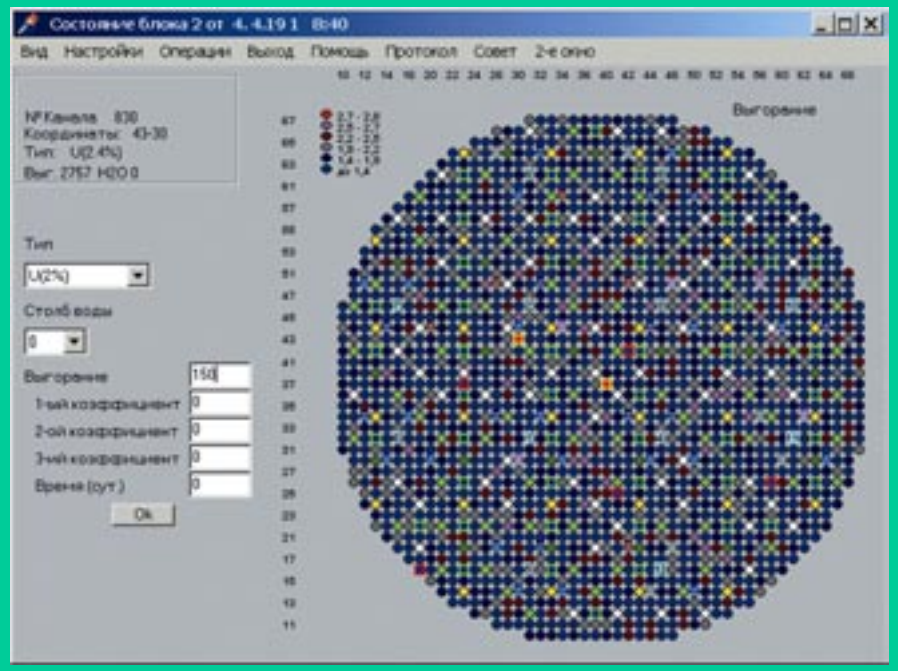
Modeling of reinforcement ropes in the form of thin sheets enables high-accuracy calculations allowing for concrete crusting



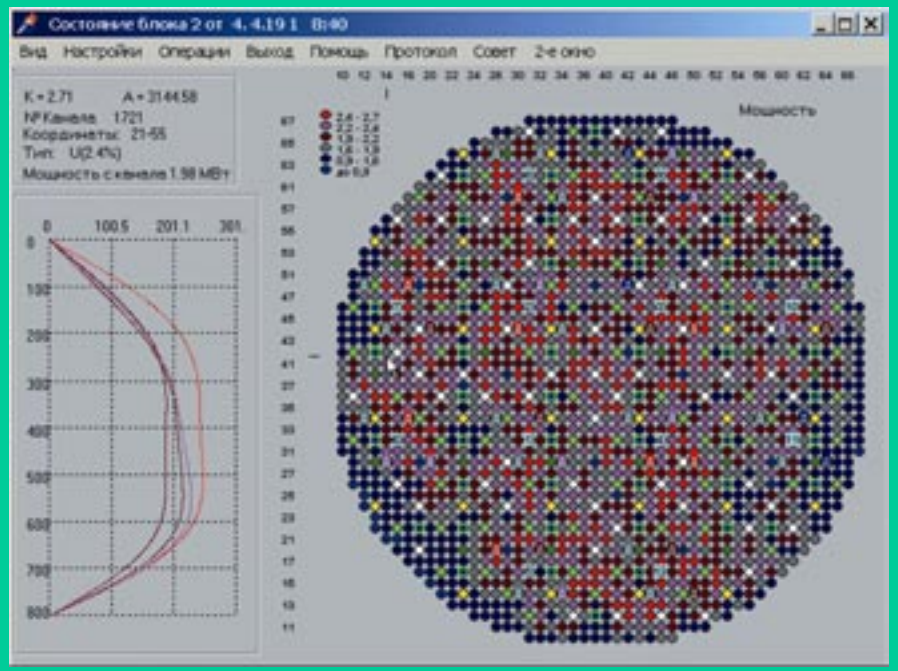
Distribution of the ring tension in the anchor pad under the rope strain N=1000 t

NPP operator support — PROGNOZ code

The PROGNOZ code package was implemented and tested at: the Ignalina NPP (Lithuania); units 1,2 of the Smolensk NPP; unit 3 of the Kursk NPP



Fragment of the reloading dialog. Color indicates the fuel burn-up rate



Map of the channel power release. Curves show the power distribution along the fuel assembly axis

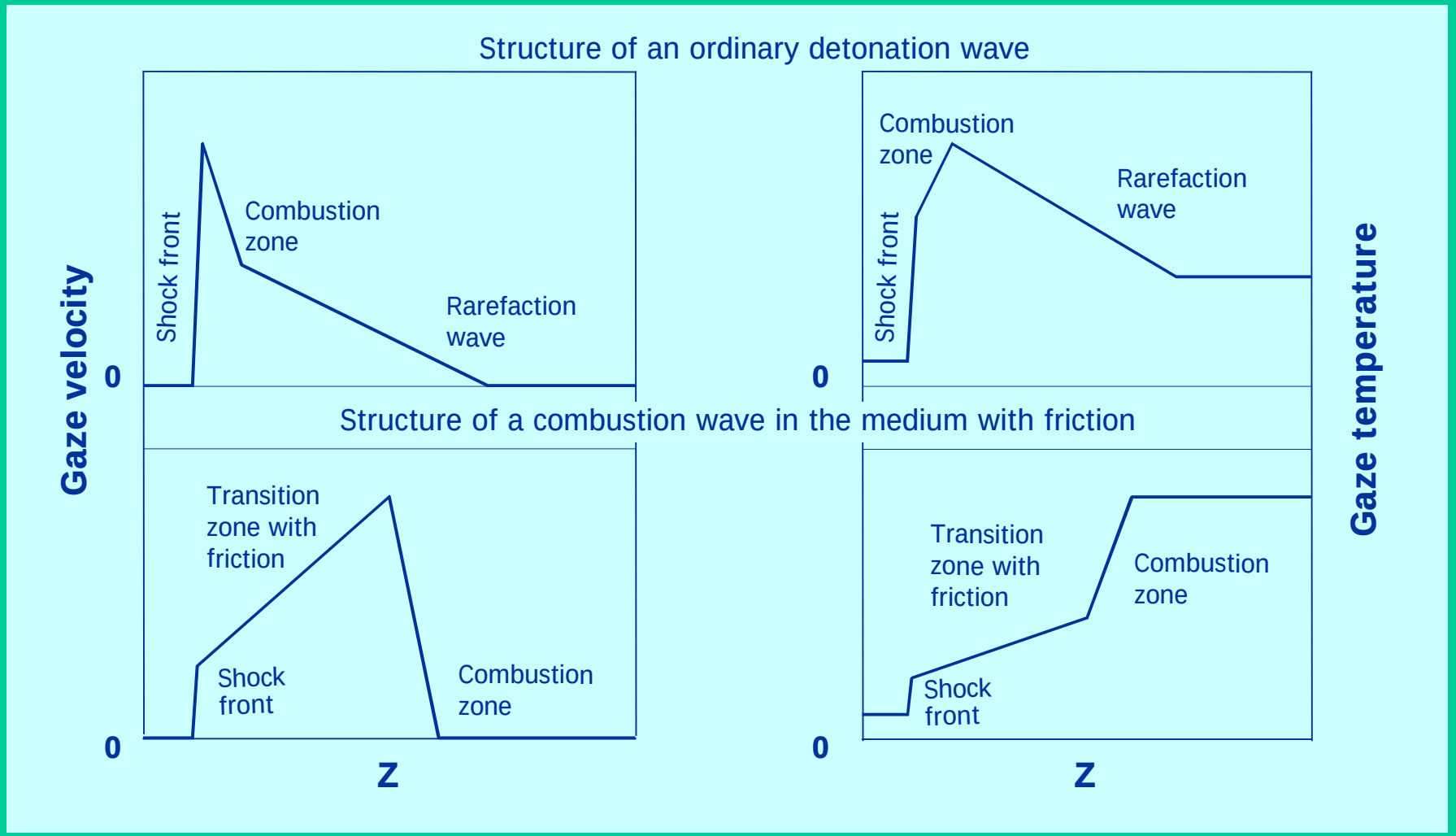
Software for processing, analysis, and visualization of information in power industry

Specialized software designed by IBRAE on the basis of the geoinformational systems are aimed at the solution of certain economical and technological problems in power production and distribution

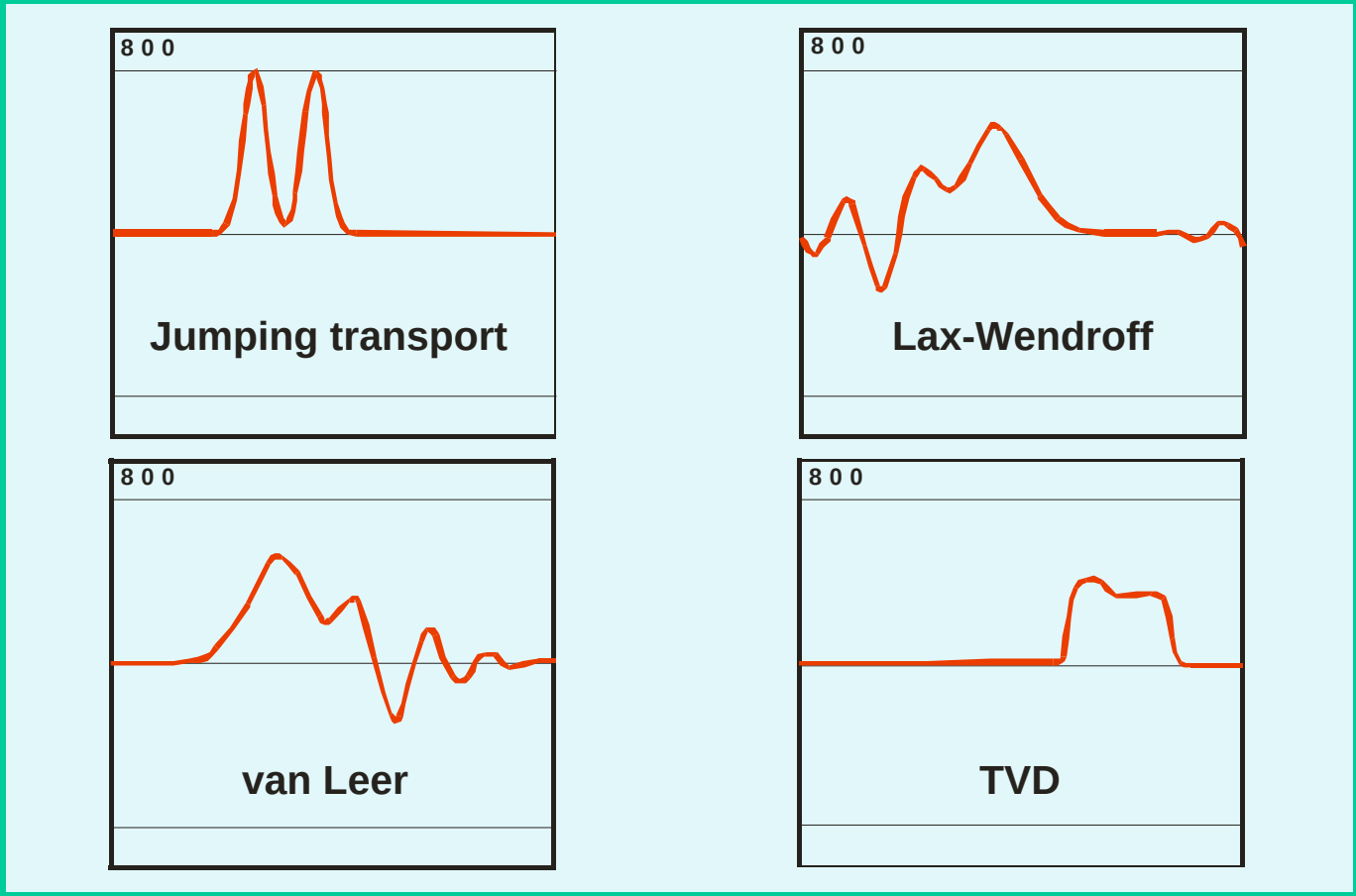
Summary and auxiliary tables for rate calculation and analysis

Aggregated power supply and sale data for the specified region

Fundamental researches. New mechanism of combustion propagation in gaze mixtures



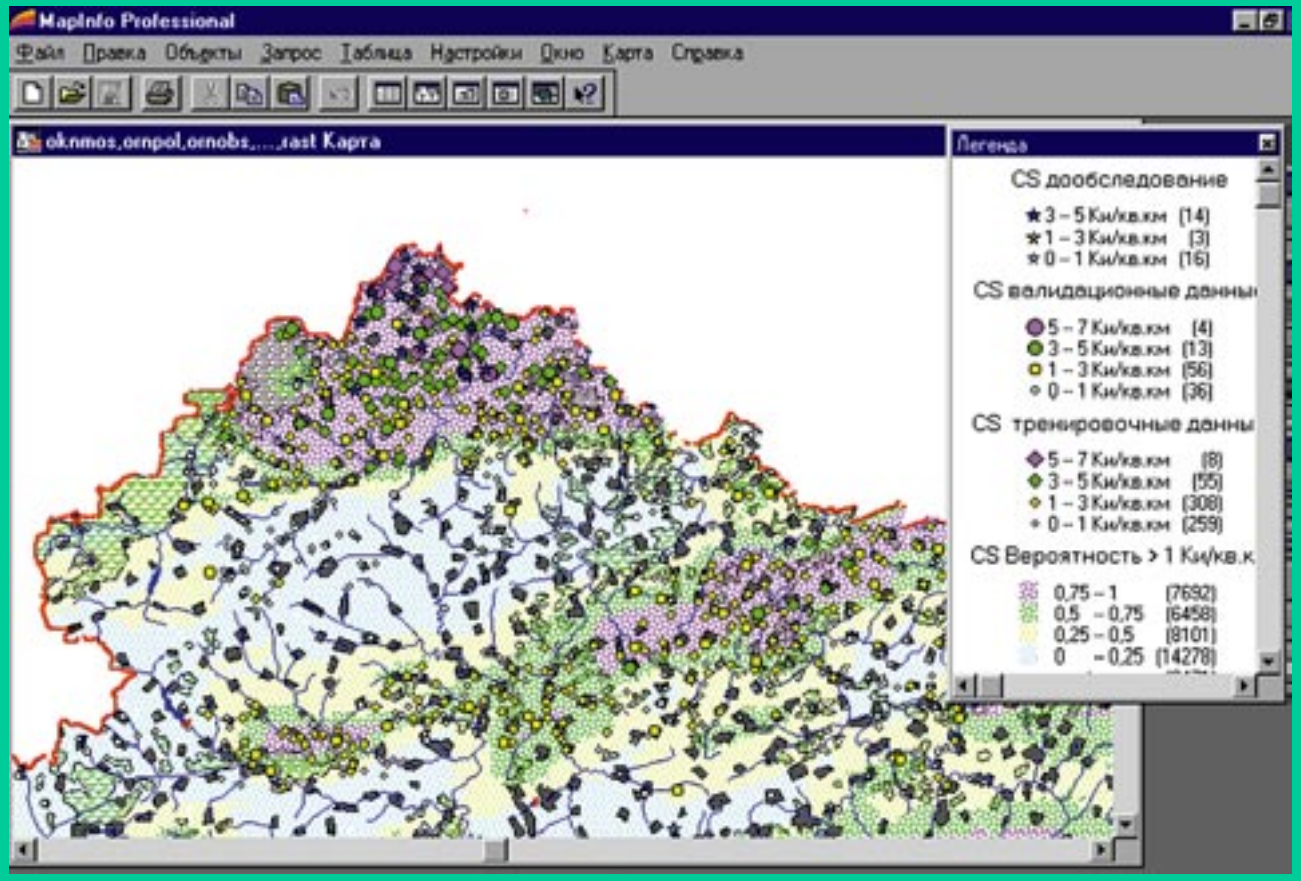
Fundamental researches. Development of new generation of efficient numerical algorithms



Calculation results for the problem of convective transport upon 800 approximation steps. The jumping transport algorithm exactly reproduces the initial perturbation profile. Other schemes result in catastrophic degradation of the initial profile .

Fundamental researches. Artificial Intelligence methods

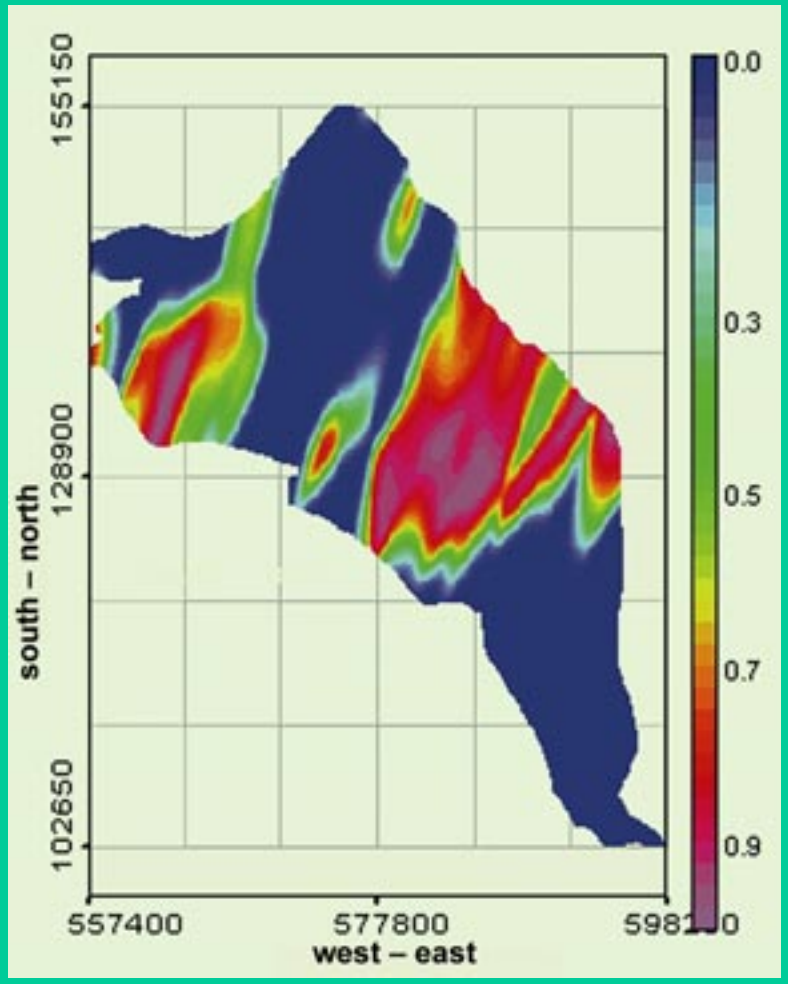
The AI methodology for the analysis of the spatially distributed data includes:

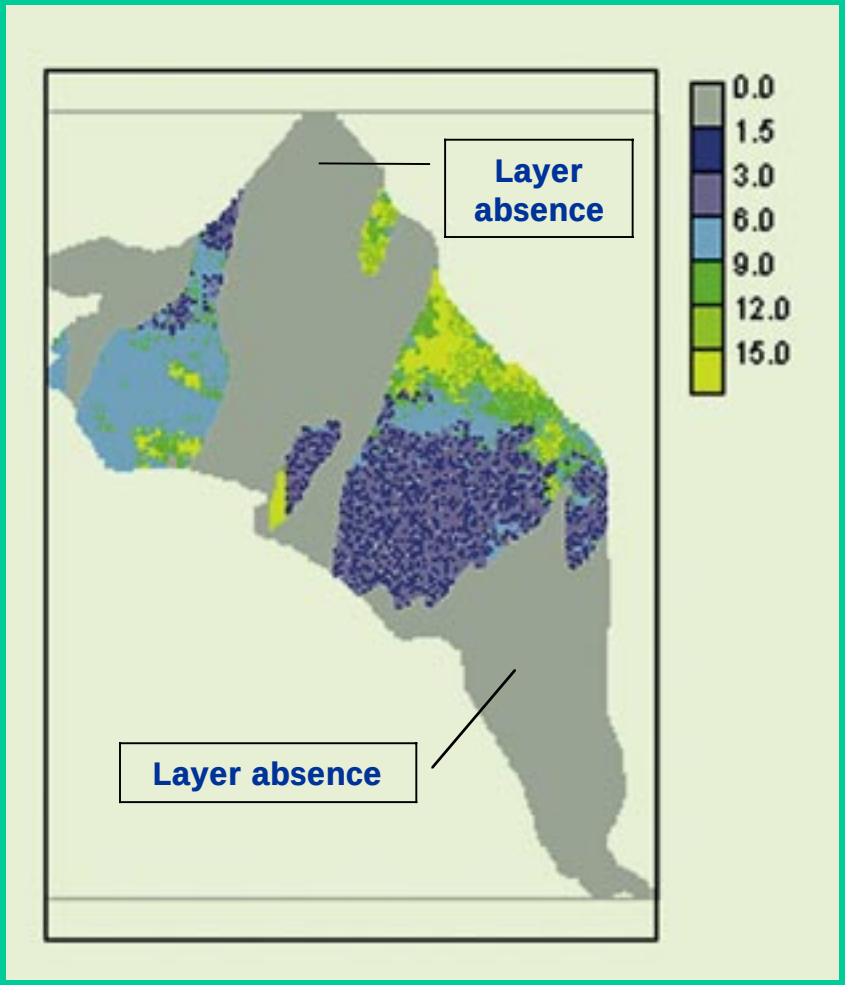


Results of the probabilistic mapping in the GIS: local probability for the surface concentration of ^{137}Cs exceeding 1 Ci/km^2

- comprehensive (geometrical, statistical, and fractal) analysis of the monitoring network;
- detailed statistical (global and local) data analysis;
- analysis and modeling of the space correlation structure;
- choice of the optimal method for the data analysis;
- representation of the obtained results in the geographic informational system (GIS).

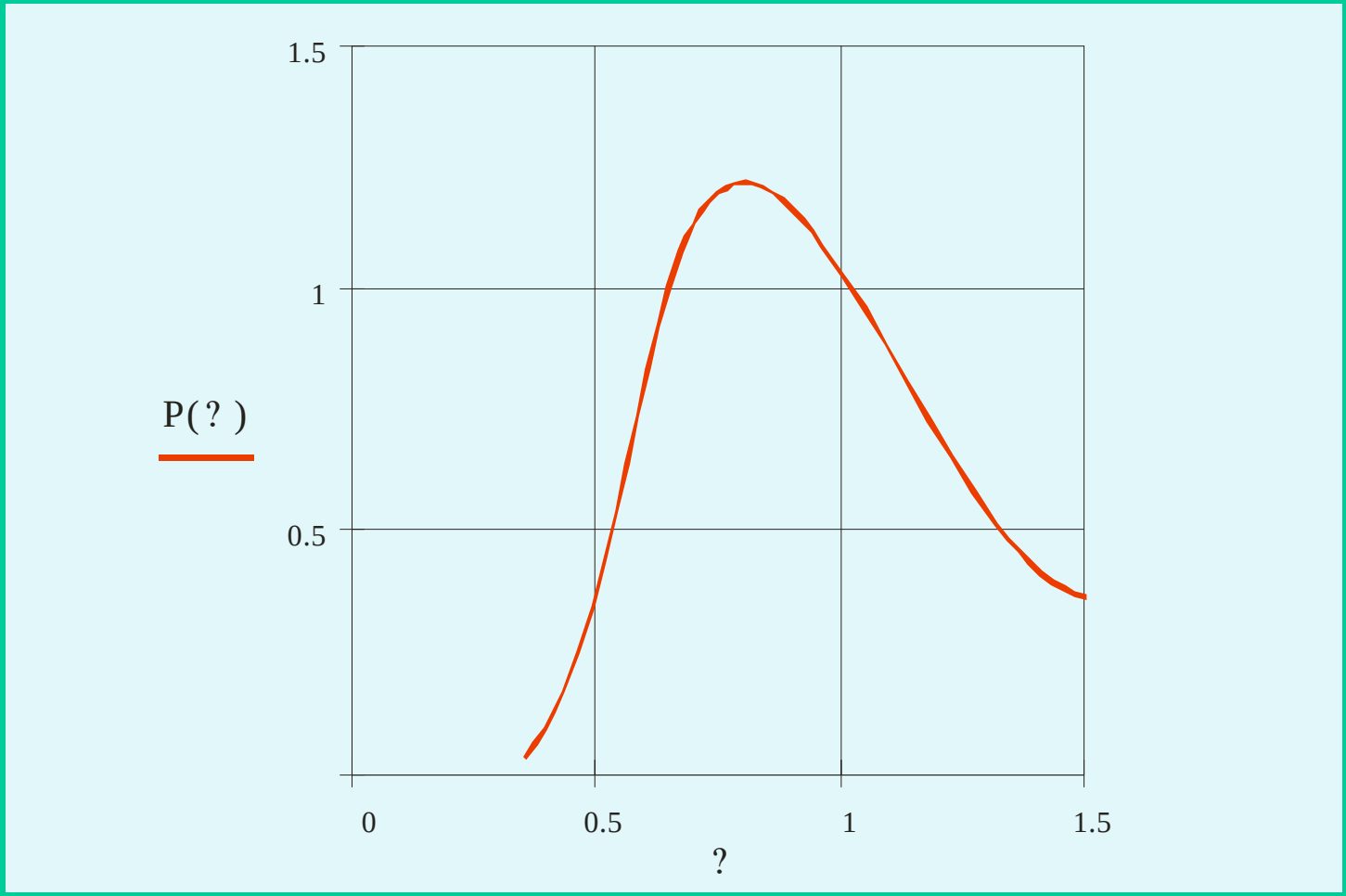
Fundamental researches. Artificial Intelligence methods





Stochastic modeling of the geological layer: the probability to find upper Ringold mud (left) at the Hanford site (USA) and sample realization of the layer depth

Fundamental researches. Contamination transfer in highly disordered media



Risk factor for the disposition of the radioactive wastes versus the square of the media interface surface

Practical experience

Accidents	Period of IBRAE's involvement
Chernobyl (1986)	1986 – 2002
South Urals (1949-1951, 1957)	1989-90, 1993-94, 1998–02
Tomsk (1993)	1993-95
Chazhma bay (1985)	1995-2002
Nuclear tests in the Altai and Kazakhstan Regions	1989-91, 1993-96, 2001

Chernobyl

1992-2002

1990-1991

IBRAE provides Information and Analytical Support to

- EMERCOM of Russia
- the Chernobyl State Committee of Russia
- the USSR Government

1988-1989 IBRAE Foundation within the Academy of Scien

1986-1988 Involvement of Experts

L. Bolshov & expert team

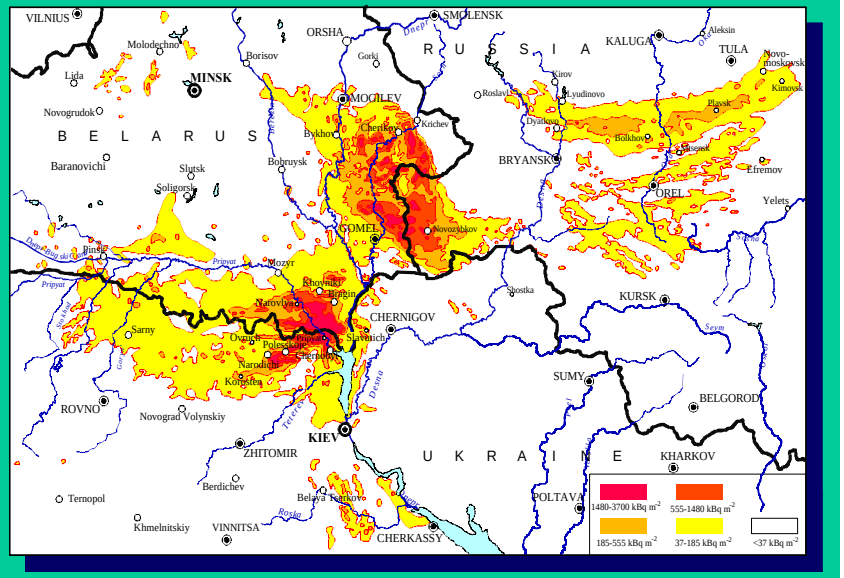
S&T-support to Governmental Commission

I.Linge & expert team

S&T-support to the Ministry of Health

Experts working at Chernobyl NPP

Chernobyl

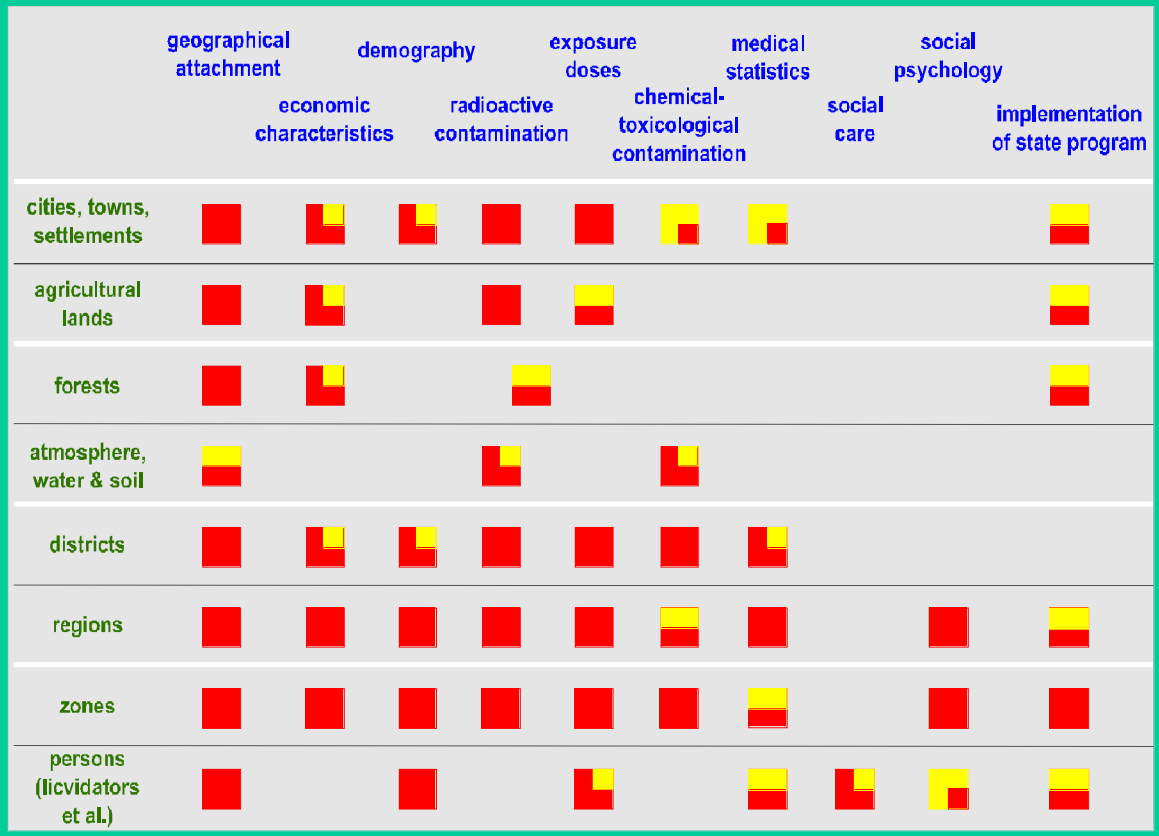


- Milestones
  - Central Bank of Generalized Data
  - Geo-Information System for Decision Makers
  - Bank of Models and Algorithms
  - Radiological Prognosis for Near and Far Future
  - Work with Local Authorities in contaminated areas
  - Work with National Authorities
  - Preparing National Programs for Authorities
  - Preparing Annual National Reports for Russia
  - Preparing Information Materials for the Public

Chernobyl

The Central Bank of Generalized Data

CURRENT STATE OF CENTRAL DATA BANK FILLING



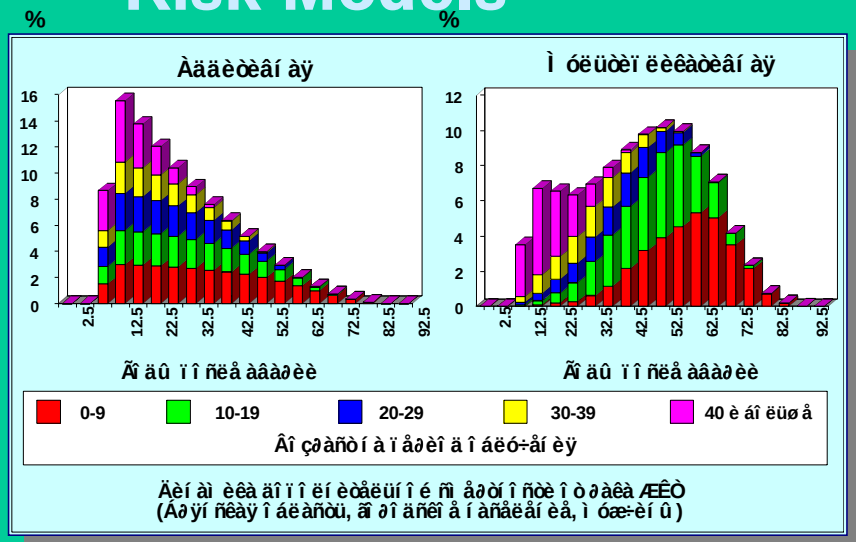
Nuc ear Safery Institute (BRAE),
Russian Academy of Sciences

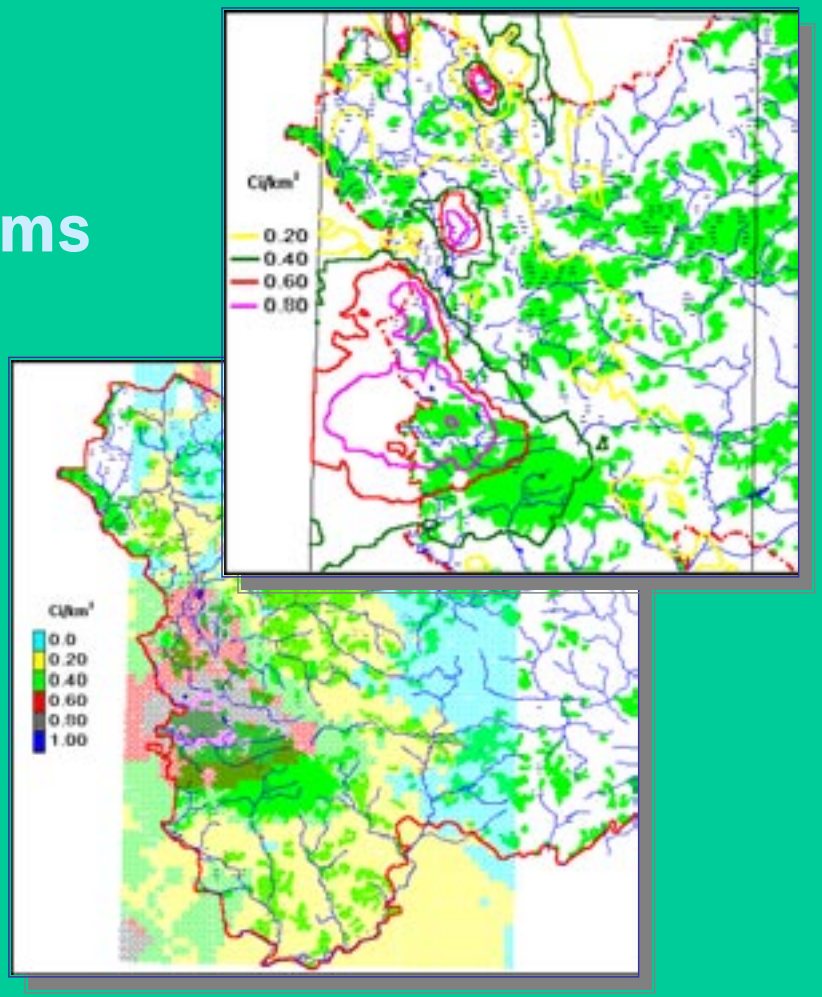
data available data bank fill in

Chernobyl

Bank of Models and Algorithms

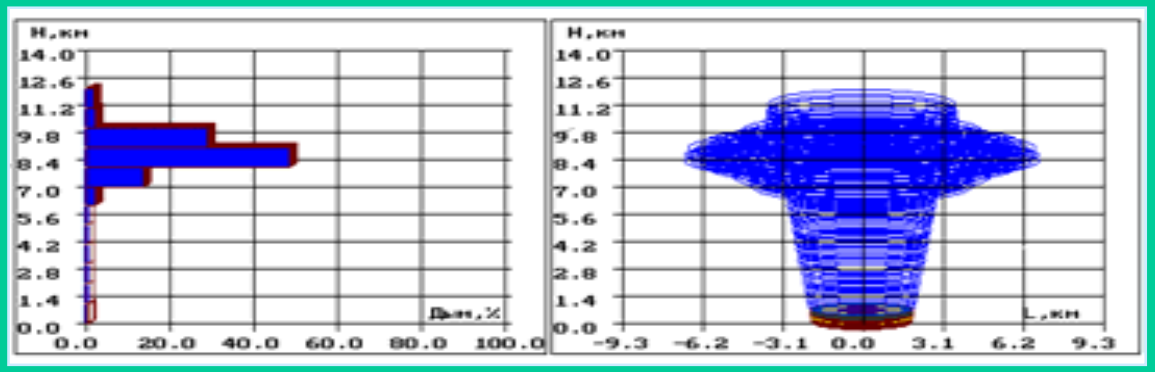
- Geo-Statistics
- Geo-Information Systems
- Prognostic Models
- Risk Models

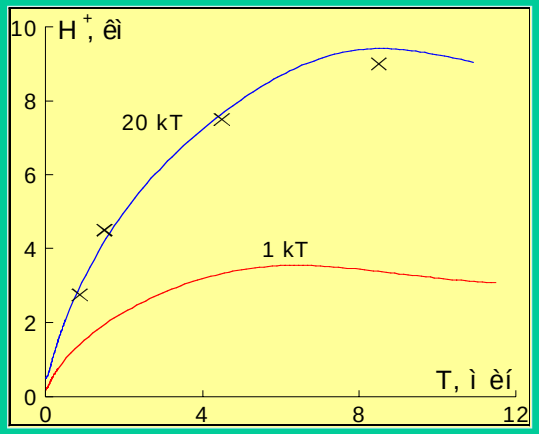




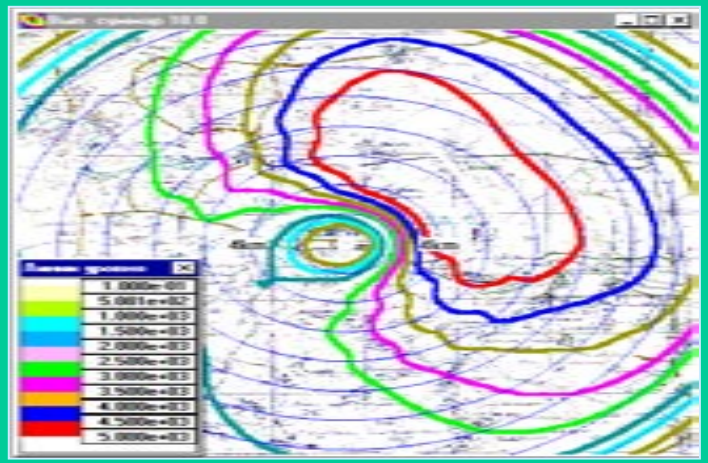
Models

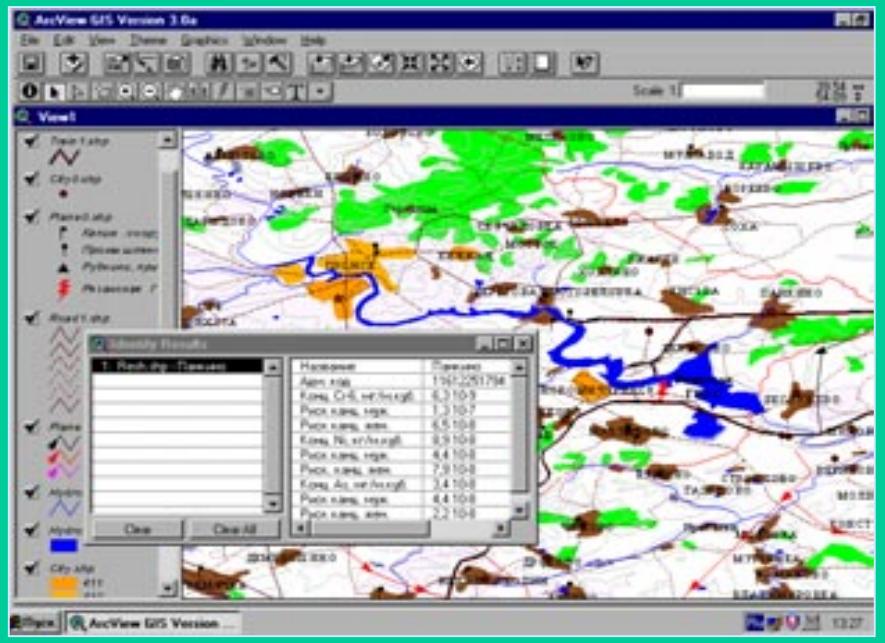
Spread of admixtures above a strong fire or explosion source



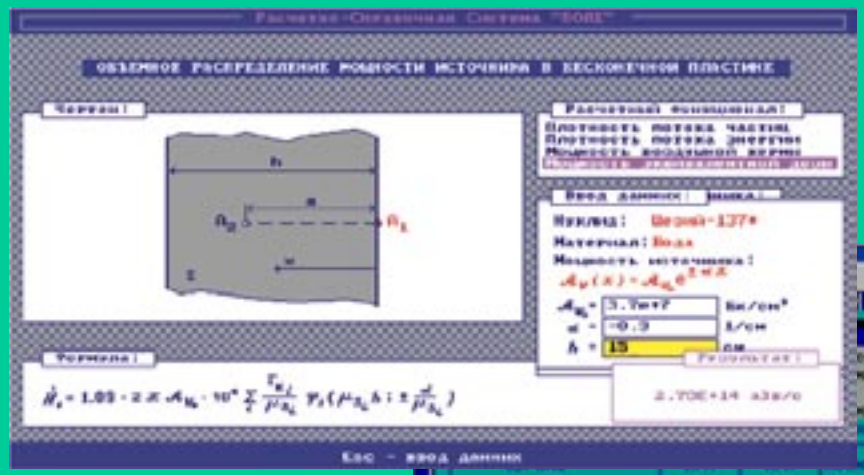


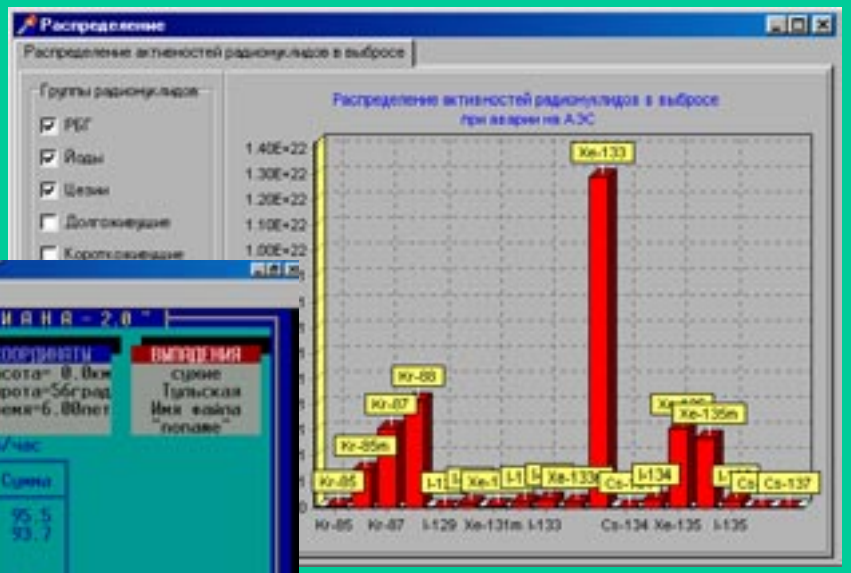
Simulation of chemical pollutants spread

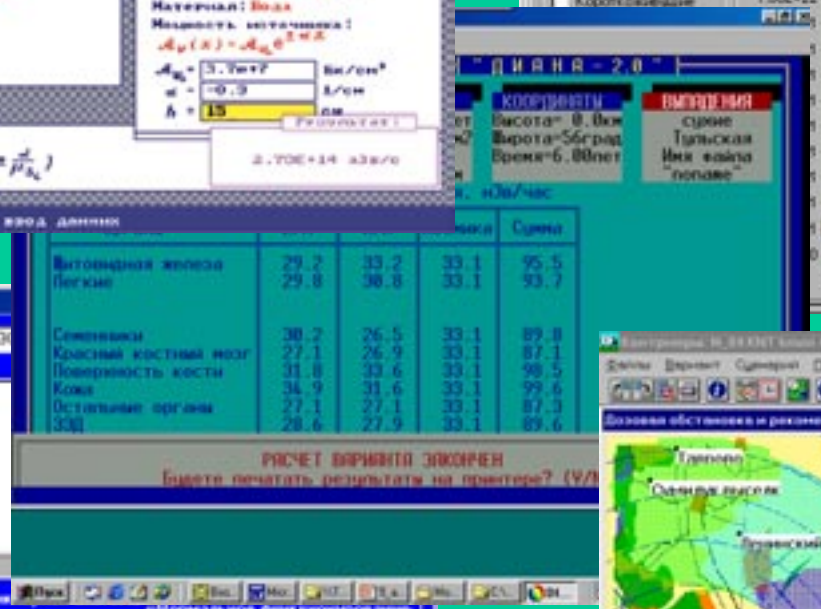


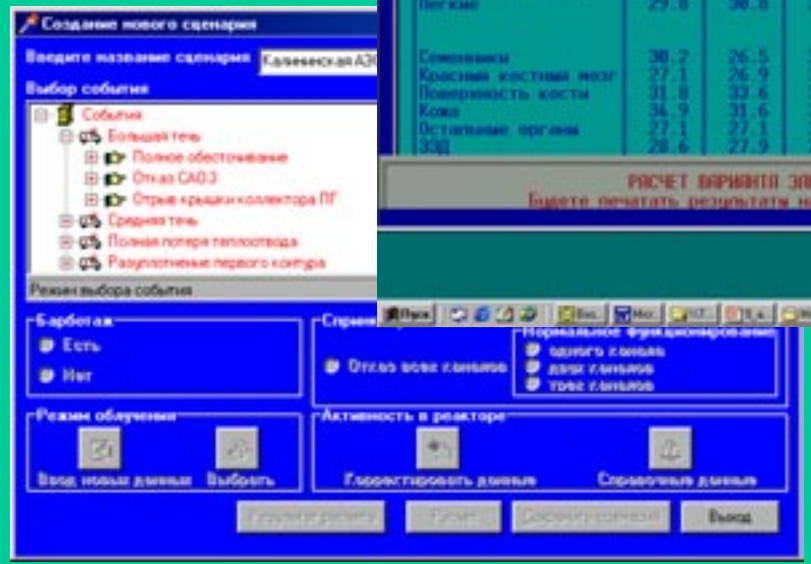


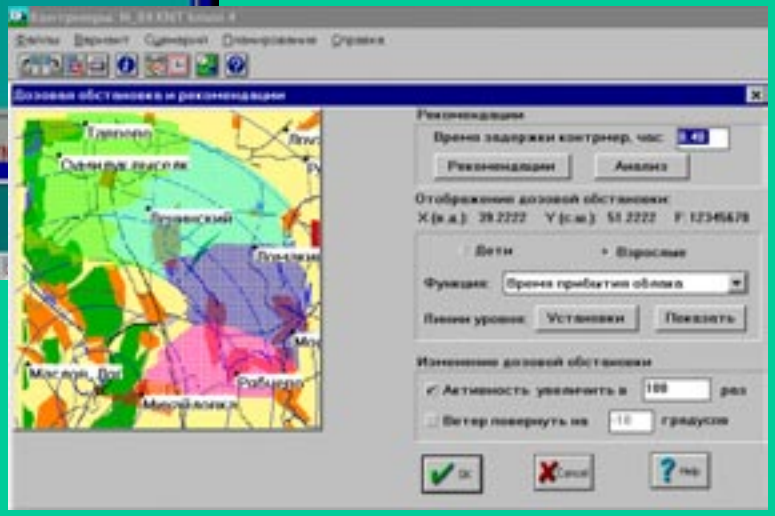
Assessments of exposure doses and recommendations on protection of the population and environment











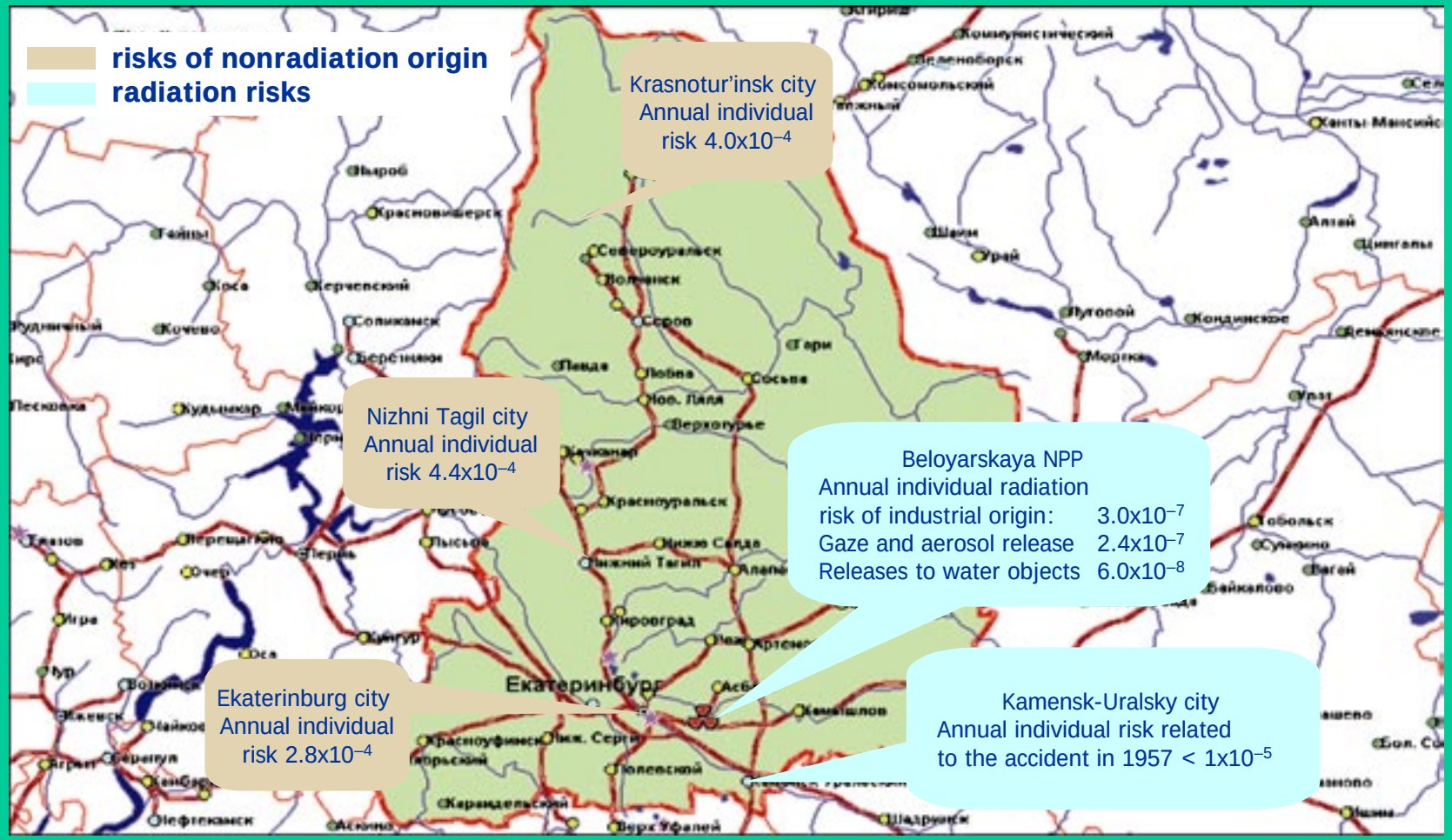
System investigation of ecological risks

Individual annual mortality risks for the population of Russia

Cause	Subject, mln. persons	Risk	Annual lethal cases
All	69(male)	2.0×10^{-2} (average over 1996–1998)	1 060 000
Accidents	69(male)	3.4×10^{-3} (average over 1996–1999)	240 000
Severe contamination of the atmosphere	70	10^{-4}–10^{-3}	40 000–70 000
Chernobyl NPP resettlement zone	0.1 (contaminated areas in Russia, Ukraine, Belorussia)	8×10^{-5}*	8*
Population in the vicinity of «Mayak», nuclear fuel plants	0.9	6×10^{-6}–3×10^{-7}*	<3*
Population in the vicinity of NPP	0.5–1	7×10^{-7}*	<0,7*

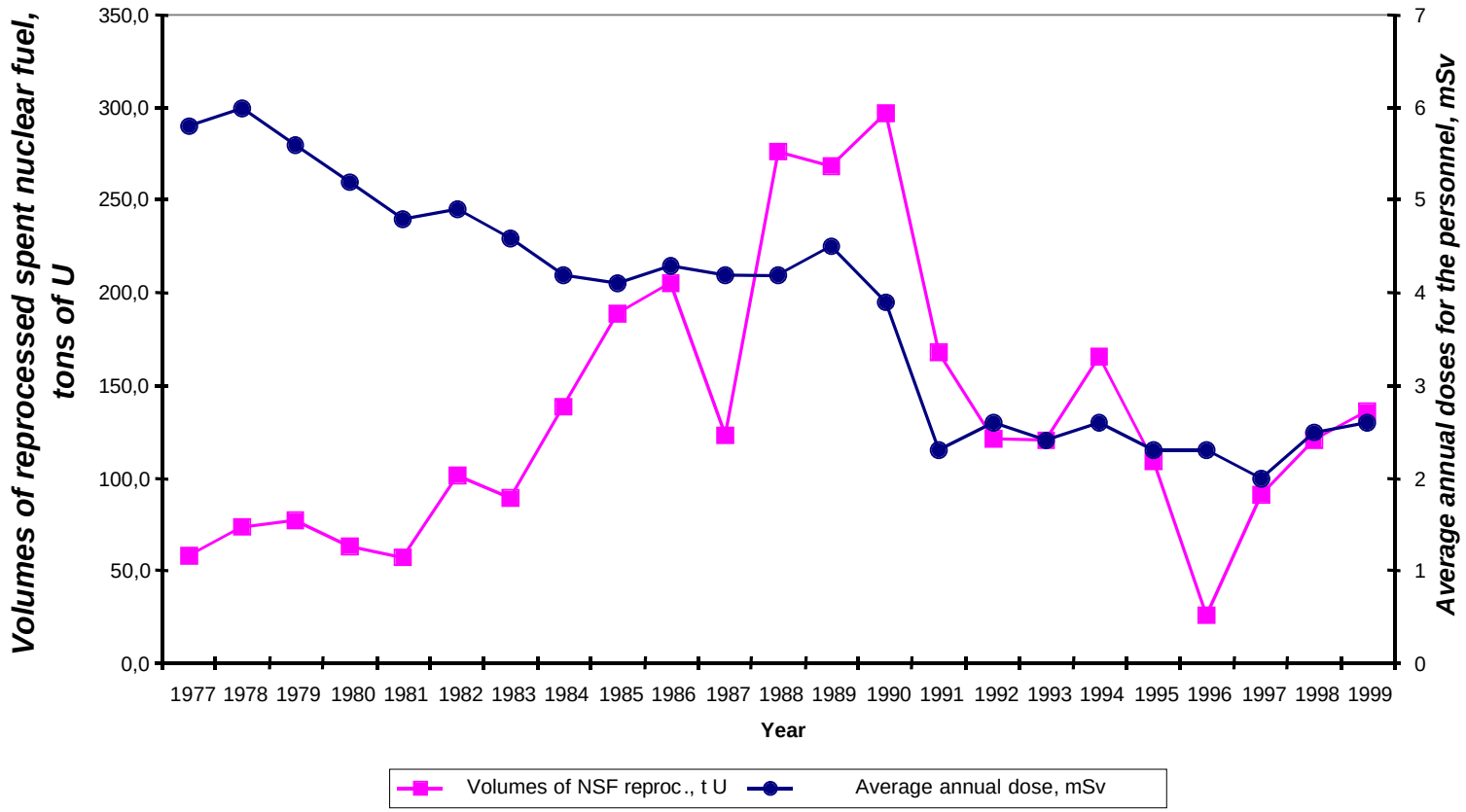
***hypothetic risks and lethal cases in the low-dose region are calculated within the linear nonthreshold model**

System investigation of ecological risks



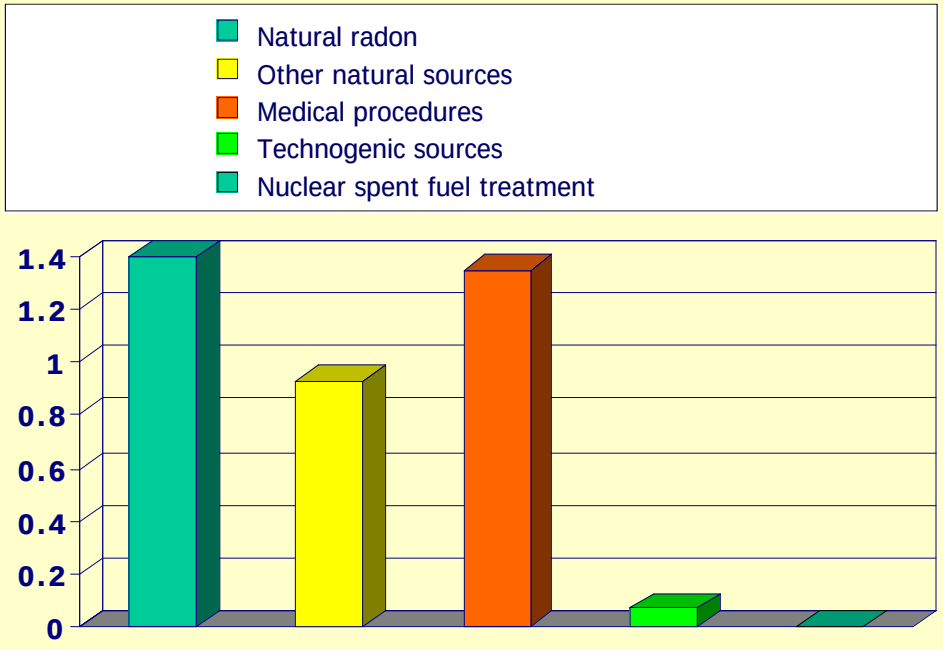
Average dose for the personnel of plant RT-1 (reprocessing) is 2.8 mSv/year, of plant RT-2 (storage) - 0.7 mSv/year. Though there are still some reserves for dose decreasing. Recent dose loads for the personnel of plant RT-1 correspond to the dose loads for the personnel of French plants at the beginning of 1990s (before modernization).

Dynamics of personnel exposure at the "Mayak" plant RT

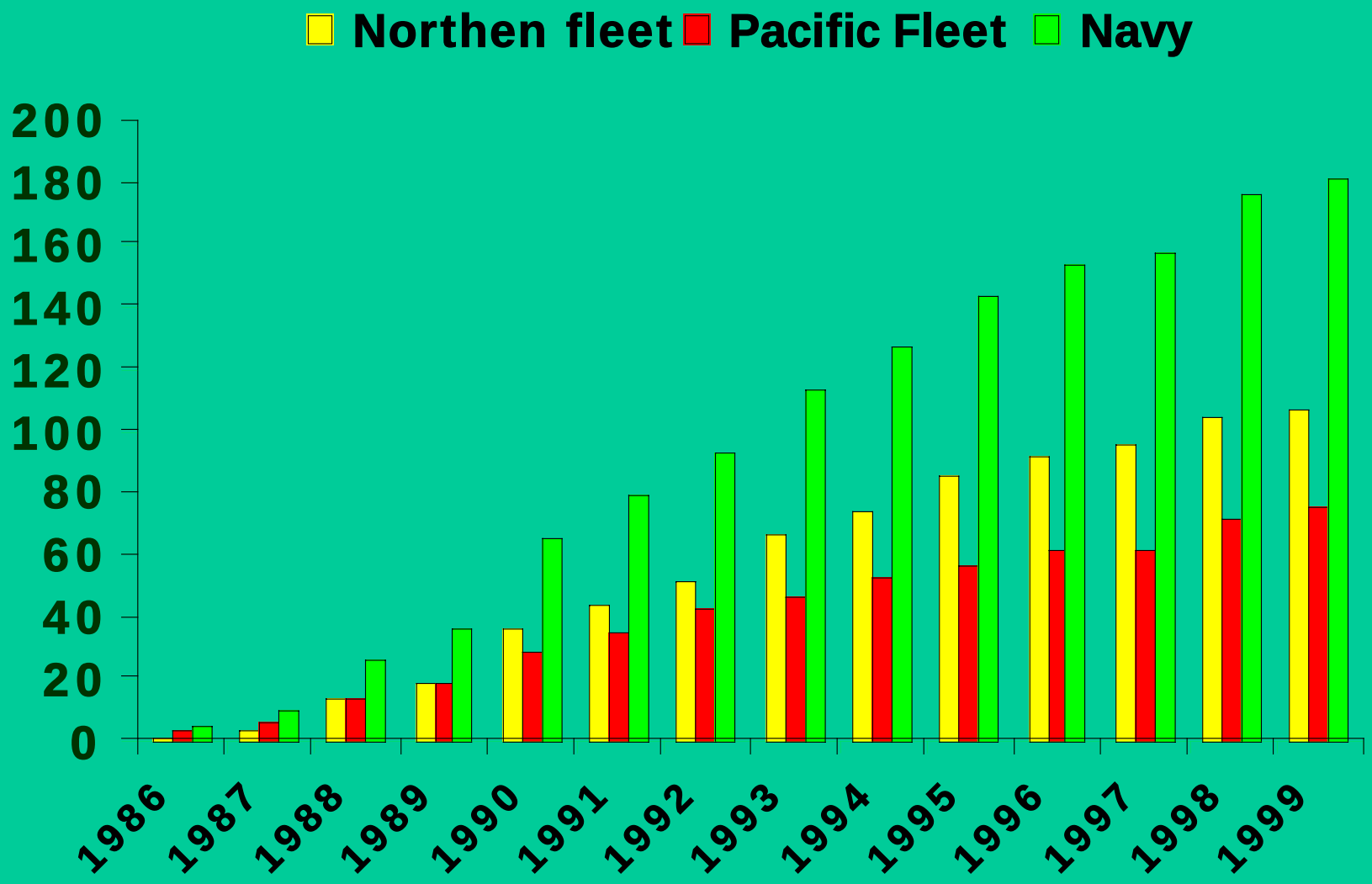


Radiation risks for nuclear spent fuel treatment

Average annual exposure doses for the population of the Krasnoyarsk Region



Navy nuclear submarines decommissioning dynamics



Creation of the radiation monitoring system at the Navy objects (AMEC project)

Structure of the prototype for the information and measurement channel

Dialog screen of the «PICASSO–AMEC» system

Depleted uranium impact

IBRAE researchers participated the activity of the multilateral expert group (MEG) charged to study possible consequences of the DU weapons used by NATO forces in Yugoslavia

Map of aerial bombardment in Kosovo, Serbia, and Montenegro (inset) by the DU-containing ammunition

120mm tank ammunition with DU core in flight

The results of the MEG studies summarized in the special report state that there are no documentary confirmed evidence of an increase in leukemia morbidity and mortality among the NATO military staff and residents in the regions of Bosnia and Kosovo bombed by the DU weapons.

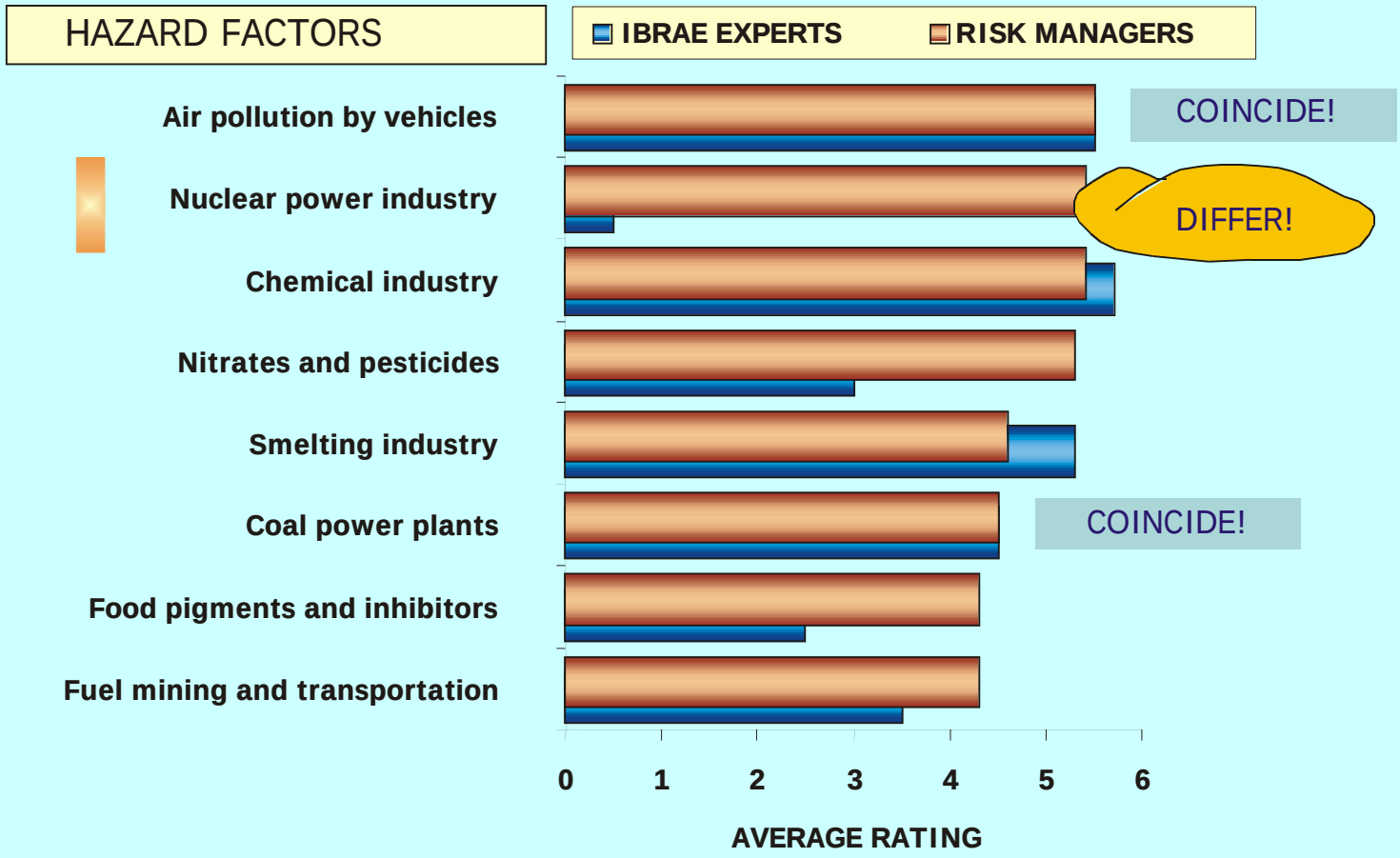
Public relations

The National Information Chernobyl Center performs testing of new forms of informational works — multimedia technologies, which enable visualization of complicated information and attract broad culture aspect to activate the emotional perception component

The gained Chernobyl experience helped to understand the reasons of public anxiety related to new nuclear technologies in Russia

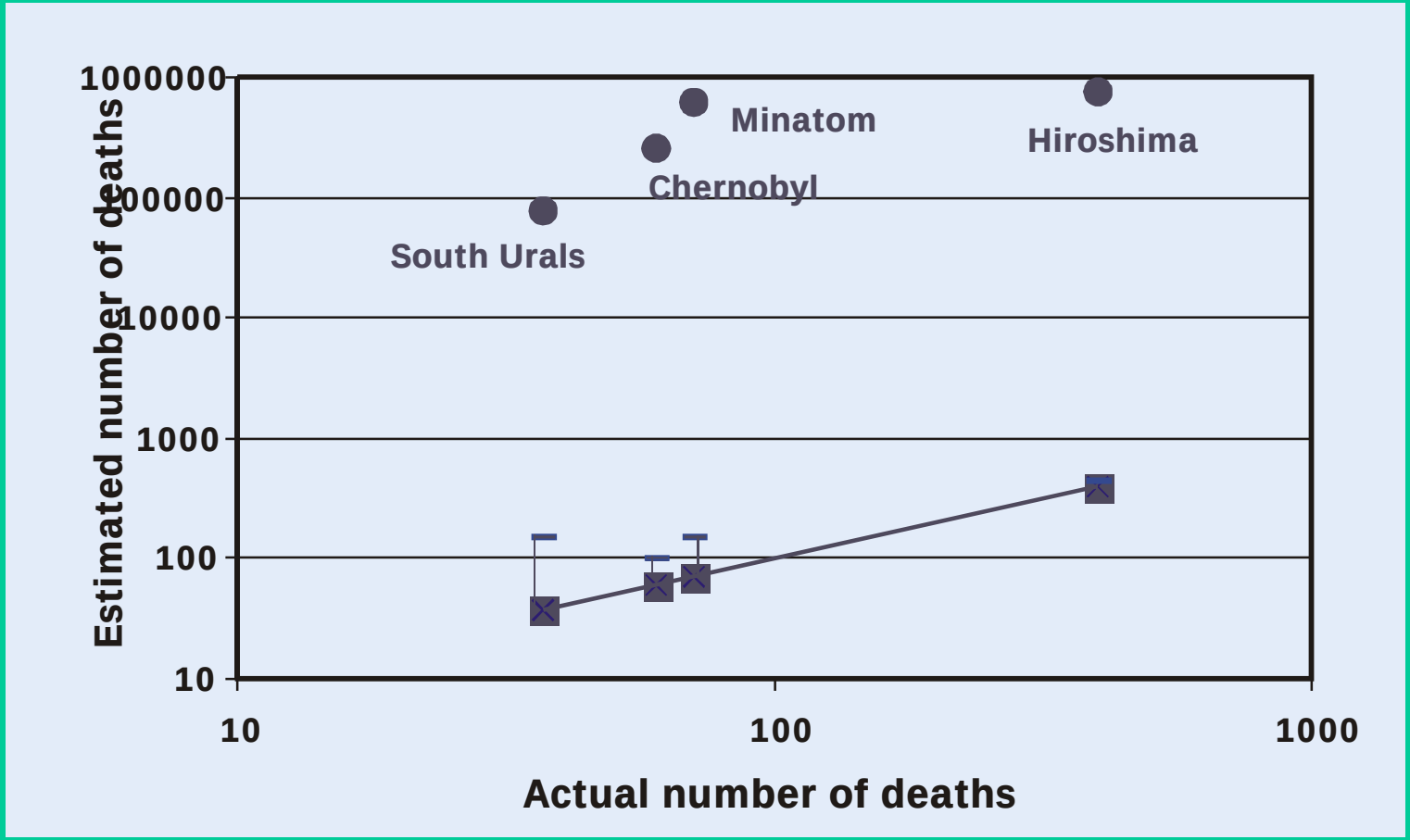
Analysis of public opinion

COMPARISON OF ECOLOGICAL HAZARDS



Comparative rating of various hazard factors by risk managers and IBRAE experts. The estimates are in a good agreement for all factors but nuclear power industry.

Analysis of public opinion



Results of the poll with the students of the Lomonosov University in Moscow «What do you know about the distant consequences of radiation accidents?»

Technical Crisis Center at IBRAE

CCES of the
EMERCOM

SCC of the
Minatom of Russia

IBRAE Technical
Crisis Center

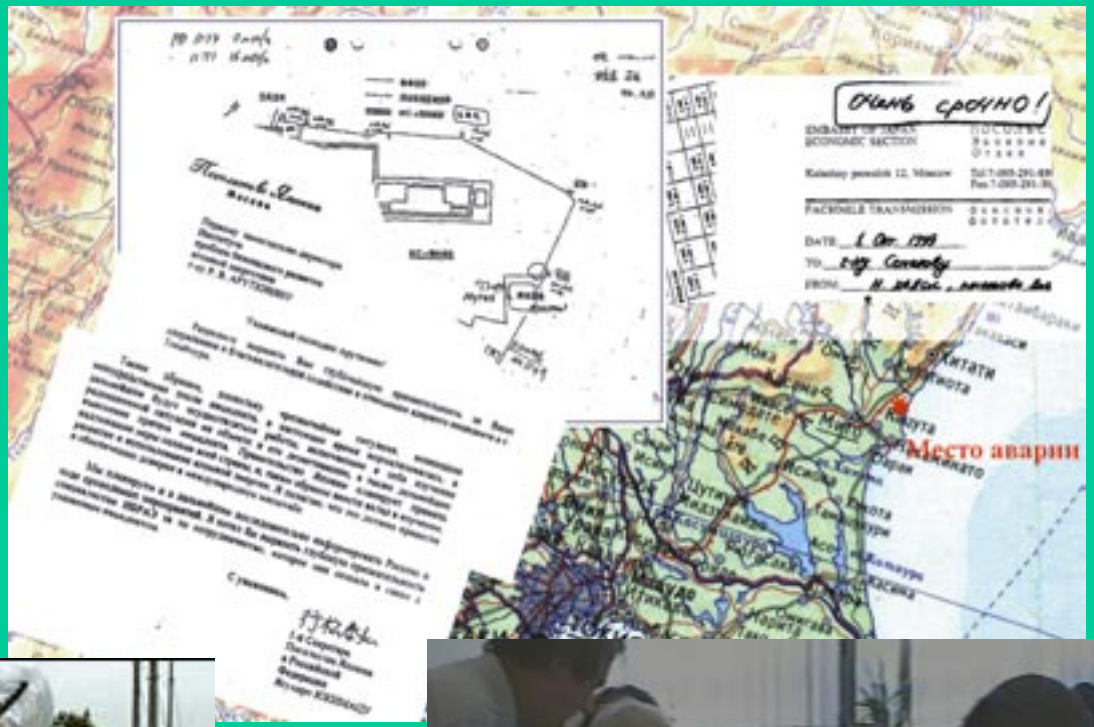
Rosenergoatom
Crisis Center

Gosatomnadzor

Interaction between IBRAE TCC and crisis centers of other state bodies

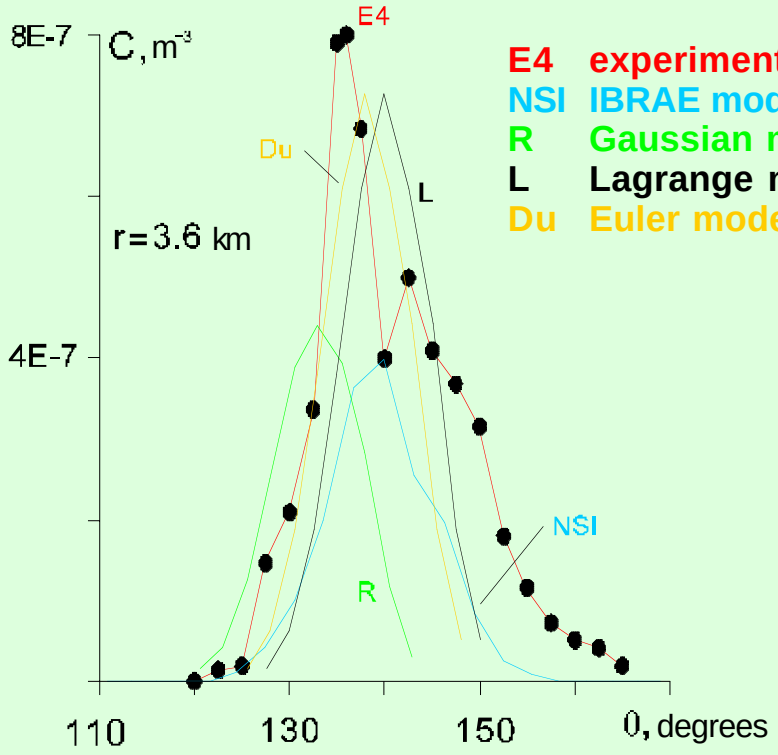
Technical Crisis Center in IBRAE. Tokaimura accident (September 1999)

According to the request of the Japan Embassy in Moscow and SCC of the Minatom, TCC IBRAE carried out real-time analysis of the radiation situation, possible consequences, and countermeasures during the accident at the nuclear fuel plant in Tokaimura (September 30, 1999)

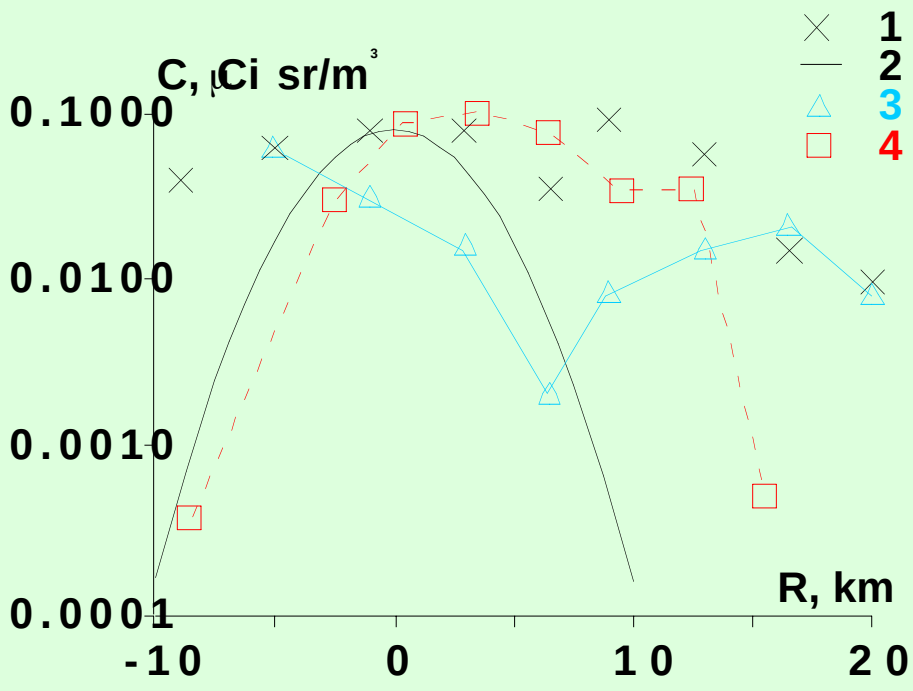


Emergency response. NOSTRADAMUS code package

Comparison of the «NOSTRADAMUS» calculations with the experimental data and other models



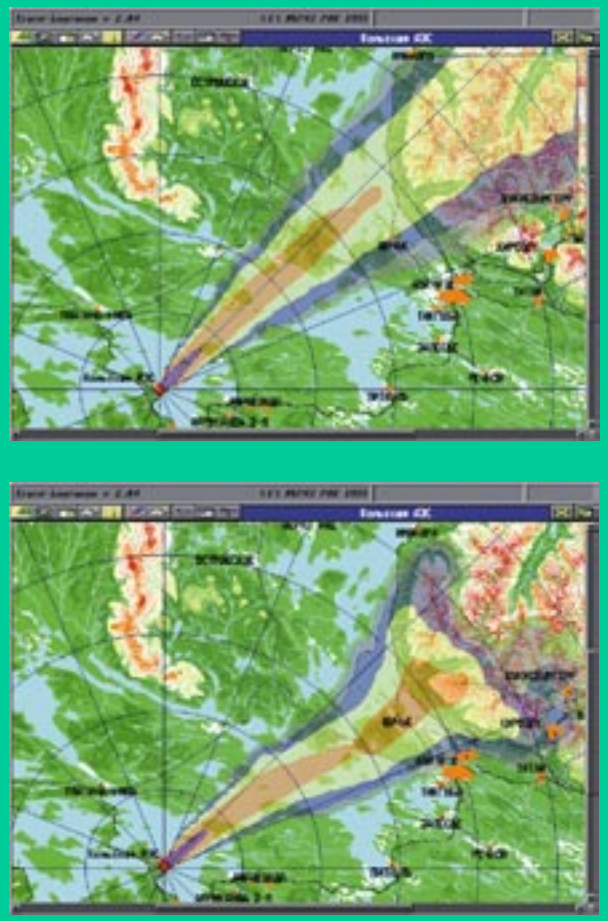
E4 experiment
NSI IBRAE model
R Gaussian model
L Lagrange model
Du Euler model



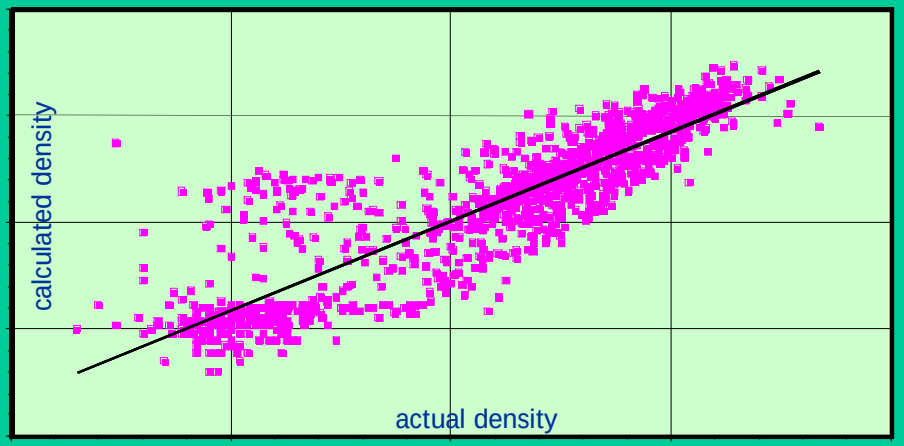
Integral surface concentration of a contaminant

Integral surface concentration of ^{131}I at the distance 60 km from the source
1 — experimental data; 2 — Gaussian model; 3 — ADPIC model; 4 — IBRAE model

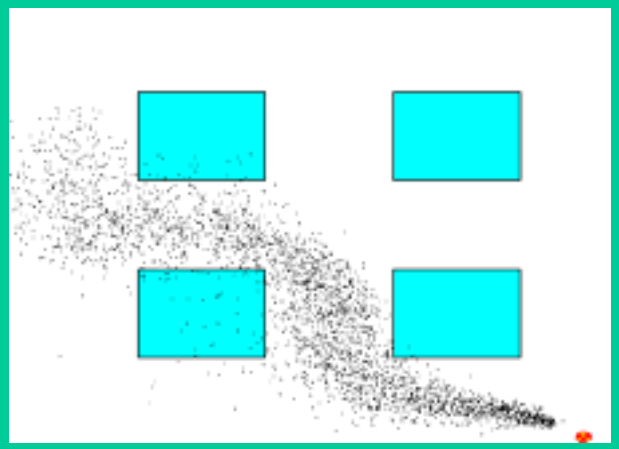
Emergency response. NOSTRADAMUS code package



Contamination density for a conditional accident at the Kola NPP calculated disregarding (top) and allowing for (bottom) the territory relief



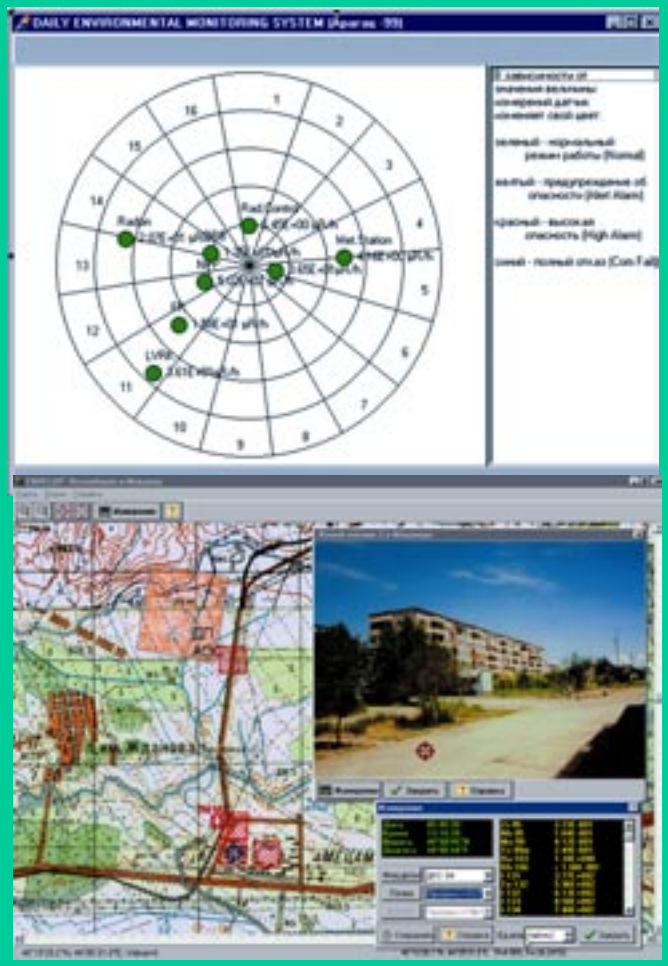
Comparison between actual (x) and calculated (y) ^{137}Cs ground contamination density after the Chernobyl accident (log-log scale)



Estimate of the radiological consequences of a radiation accident under urban conditions

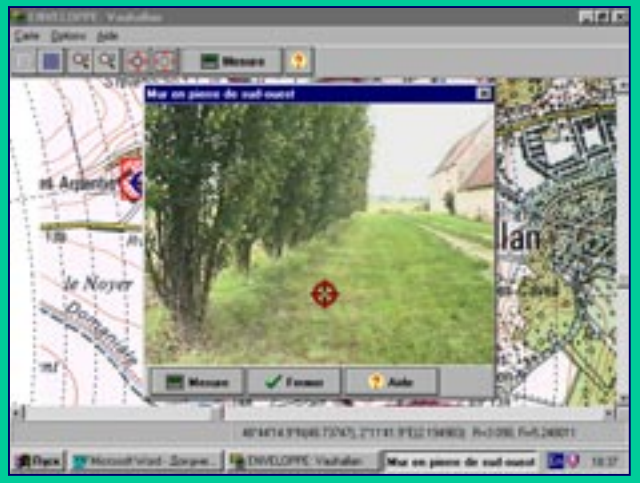
Training and Exercises

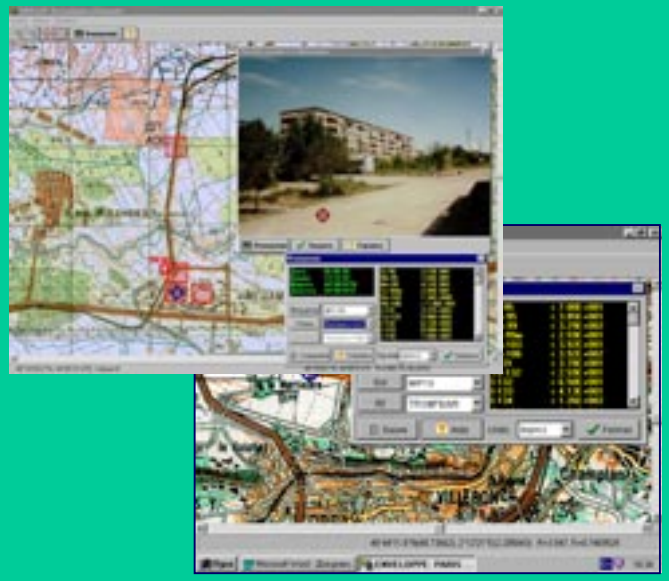
Starting from 1993, IBRAE participated in preparing and conducting trainings and exercises



IBRAE designed specialized software used in a number of Russian and international trainings and exercises aimed at safety improvement of nuclear power facilities. Shown examples are the dialog screens of «ACRS-Aragatz» (top left), «ENVELOPE-Aragatz» (bottom left) and «ENVELOPPE» (right) code packages

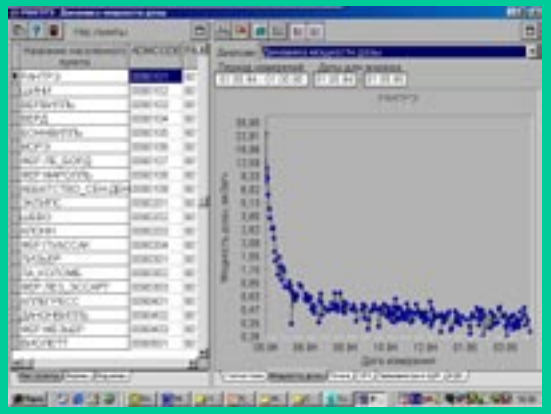
Systems for simulations of radiation measurements by mobile groups of radiation survey



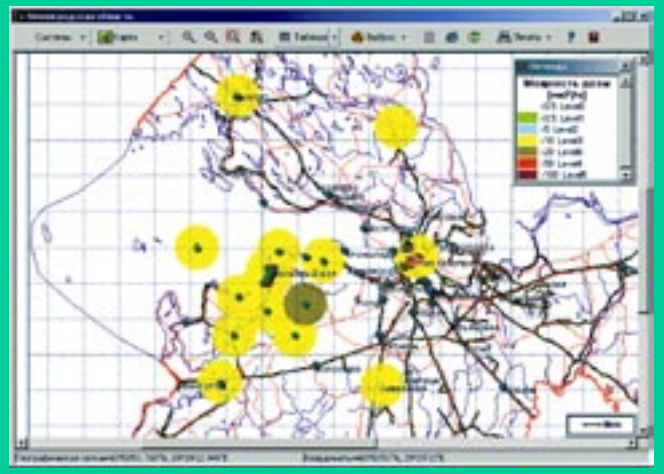


Application in:

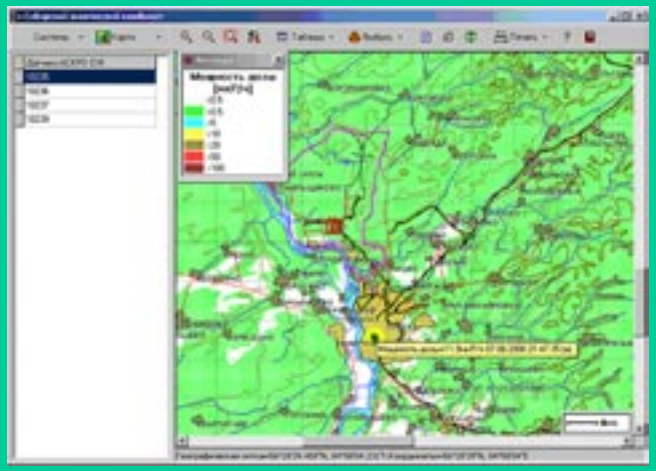
- international and national business games:
  - Becquerel (France, 1996)
  - Aragats – 99 (Armenia)
- training exercises for radiation survey groups of Minatom of the RF, civil defense, etc.



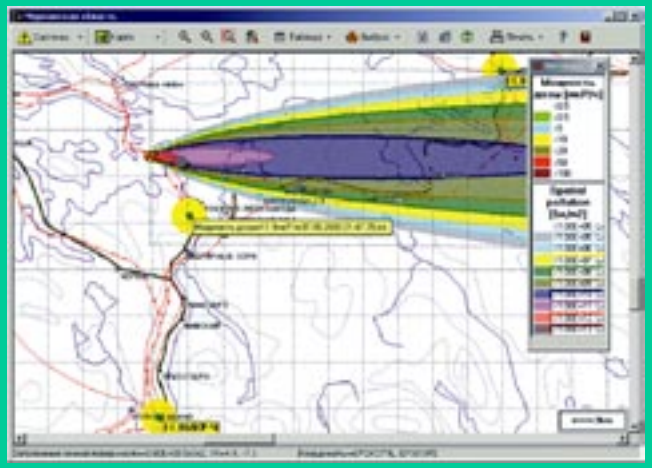
Information and analytic systems for the Situational Crisis Center of the Minatom of Russia



Visualization of the data obtained from the ACRS system (Leningrad region)



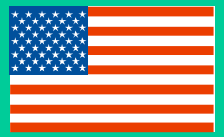
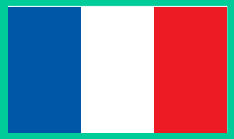
Map of radiation monitoring sensors in the vicinity of the Siberian chemical plant



Example of the modeling data presentation

Visualization of the radiation monitoring data at the NIIAR site

International cooperation

Country / Organization	Formal background of the cooperation	Area of cooperation
Europe		
IAEA	Contracts	Databases on NPP components and materials
CEC / TACIS	Contracts	Safety of the nuclear power industry objects, radioecology
OECD / NEA	Large-scale international projects	Safety of the nuclear power industry objects
IRSN (France)	Long-term cooperation agreement, contracts, international projects, French-German Chernobyl Initiative	Safety of the nuclear power industry objects, radioecology, emergency response
FZK (Germany)	Contracts	Safety of the nuclear power industry objects
GRS (Germany)	French-German Chernobyl Initiative	Radioecology
FFI (Norway)	AMEC Program / contract	Radioecology
USA		
US DOE	JCCRER Agreement, INSP Program, Memorandum of Understanding Between U.S. DOE and RAS	Safety of the nuclear power industry objects, radioecology, emergency response
US NRC	Long-term cooperation agreement	Safety of the nuclear power industry objects
US DOD	AMEC Program / contract	Radioecology, emergency response
PNNL	INSP Program, Memorandum of Understanding Between U.S. DOE and RAS / contracts	Safety of the nuclear power industry objects, radioecology
ANL, BNL, INEEL, Sandia	INSP Program, AMEC Program, Vadose Zone Roadmapping Program	Safety of the nuclear power industry objects, radioecology, emergency response